APPENDIX A

TREATABILITY LABORATORY REPORT
FEASIBILITY STUDY
SOUTH CAVALCADE SITE
HOUSTON, TEXAS

Prepared for:

KOPPERS CO., INC.
PREVIOUSLY OPERATED PROPERTY
PITTSBURGH, PENNSYLVANIA 15219

Preapred by:

KEYSTONE ENVIRONMENTAL RESOURCES, INC.
440 COLLEGE PARK DRIVE
MONROEVILLE, PA 15146

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EXECUTIVE SUMMARY

This report details the results of a treatability laboratory study performed by Keystone Environmental Resources, Inc. (Keystone). This study was designed to technically evaluate selected treatment technologies for their feasibility for treating South Calvalcade site soil and groundwater samples which contain elevated concentrations of the site chemicals of interest.

This site is called the South Calvalcade site and it is located in Houston Texas. A wood preserving plant formerly owned by the Koppers Corporation was previously operated at this site, and coal tar and creosote compounds were used in the process, and therefore comprise the majority of the site chemicals of interest.

Groundwater and Soil Samples

The groundwater used in this treatability study was a composite from wells OW-10 and OW-11, located in the formerly identified process area. The groundwater sampled settled relatively oil and solids free, by quiescent gravity settling, with small oil layers on top and on the bottom of the water samples. Therefore supernatant from the middle portions of the settled 55 gallon barrels was used for all groundwater testing experiments.

Soil samples were collected from area A-04 identified as an old creosote dumping area, between soil borings A04-SB01 and A04-SB02. Two 5 gallon buckets were taken from a depth of 10-11 feet, and one bucket was sampled from the surface to 1 foot deep. Both of these sample depths contained PAH compounds at elevated concentration levels - as high as 8 g Total PAH/1 Kg Soil (0.8%). Measurements of PAH soil concentrations varied widely despite good sampling and analytical techniques used, due to the heterogeneous nature of the contaminated soil matrix. A statistical analysis was performed on the six measured PAH concentrations of the untreated raw soil samples obtained in this laboratory work. The average mean PAH concentration obtained was 3.7 g Total PAH/1 Kg soil (0.37%). This mean concentration value was used throughout the study as the raw untreated soil PAH concentration value.

Polymer Treatment

Polymer treatment of site groundwater for oil water separation was performed using standard jar testing techniques. Various types an dosages of polymers were tested to flocculate the oil phase into a stable sludge. The two most successful combinations tested were Drew Chemical Company's products:

Amerfloc	10 @ 300 ppm
Amerfloc	5,260 @ 4 ppm
	and
Amerfloc	10 @ 300 ppm
Amerfloc	5270 @ 4 ppm

The sludge generation estimate from the jar testing experiments was 11.2 gallons of wet sludge produced per every 1000 gallons of groundwater polymer treated (1.12 vol. %). Oil and grease concentrations were reduced over 90% by polymer treatment, and over 86% by physical separation alone. The PAH concentration was reduced 73% in the physical separation test, indicating that the majority of PAH components are in the oil phase. Therefore polymer additions for oil/water separation were unnecessary for the groundwater samples used throughout the laboratory testing work.

UV/Oxidation

Chemical oxidation testing using ozone in conjunction with ultraviolet light was performed. An ozone/UV screening run was first performed in order to determine the optimum ozone dosage rate for treating the site groundwater. The treatment indicator parameters monitored in this screening run were pH, TOC, phenol (4-AAP), and naphthalene. The average ozone utilization rate was 59 percent and the optimum ozone dosage was 285 mg/l (a 10 minute reaction time).

A plot of both phenol and naphthalene concentrations versus ozone applied was drawn using a least squares regression fit technique. The slope of these lines k, is the first order decay rate constant. This k rate constant is a measure of the performance of the test, i.e. a negative k rate indicates reduction of the monitored indicator parameter, a positive k rate indicates an increase in concentration of the monitored

parameter. The lower the k rate, the better the performance obtained in the ozone/UV screening run test. The k rates obtained in the screening run tests were:

Phenols (4-AAP) = -0.0077
Naphthalene = -0.0046

The influent phenols (4-AAP) concentration of 4.95 mg/l was reduced 98.9% to 0.053 mg/l after 10 minutes of ozone/UV treatment, the naphthalene influent concentration of 65.1 ug/l showed an increase to 459 ug/l after 3 minutes of ozone/UV treatment, then decreased steadily thereafter until it was below the detectable concentration limit after 30 minutes of ozone/UV treatment.

A final sampling ozone/UV run was performed at an ozone dosage of approximately 285 mg/l (a 10 minute reaction time). Enough batch runs were performed to generate sufficient sample for all of the site chemicals of interest.

The average ozone utilization efficiency obtained was 57 percent, duplicating that of the screening run test. Also duplicated was the reduction in phenols (4-AAP) at 98.4 percent after 10 minutes of ozone/UV treatment. The pH of the groundwater changed very little by the ozone/UV treatment, 6.7 to 6.4. No effect was seen for most of the other conventional pollutants or metals. Total PAH concentration was reduced 52.5 percent, with the lower molecular weight 2 and 3 ring PAH components showing higher levels of reduction.

The groundwater tested "toxic" in the Microtox™ bioassay test both before and after ozone/UV treatment. The ozone/UV treated effluent decreased in Microtox toxicity by 8 percent.

Activated Carbon

The feasibility of treating site groundwater with activated carbon was tested using both isotherm testing and packed column testing. The isotherm work was performed by Keystone and will be described first. The column testing was subcontracted to the Calgon Corporation laboratories in Pittsburgh Pennsylvania which used their Accelerated Carbon Testing (ACT) test method.

The isotherm experiments performed by Keystone utilized Calgon's F-300 granular activated carbon, pulverized so that 95 wt. % passed through a 325 mesh screen. Twelve different weight ratios of activated carbon to site groundwater were shaken for 1 hour and then the liquid was separated from the carbon by filtering. The liquid phase was analyzed for TOC, phenol and pH.

The maximum adsorption capacity of the activated carbon for naphthalene, phenol and TOC were estimated by plotting the concentration of the parameter in solution (at equilibrium) versus the total weight of the parameter adsorbed per unit weight of carbon. The best fit line for the data was drawn by a computer program using a linear regression technique and an equation which describes the line drawn, was generated. Solving this equation for the influent concentration of each parameter yielded the maximum adsorption capacity for that parameter by the F-300 activated carbon, for the groundwater tested.

Based upon an influent concentration of 2.74 mg/l of naphthalene, the estimated carbon usage from the isotherm testing is 0.85 pounds per 1000 gallons of groundwater treated. The estimated carbon usage rate for an influent TOC concentration of 56 mg/l is 2.08 pounds per 1000 gallons of groundwater treated. The estimated carbon usage rate for an influent phenols (4AAP) concentration of 7.45 mg/l is 4.67 pounds per 1000 gallons of groundwater treated.

ACT Results

Keystone contracted the Calgon Corporation to perform their Accelerated Carbon Test (ACT) on a sample of gravity settled site groundwater supplied to them by Keystone. The ACT test simulated carbon adsorption treatment in a packed carbon column.

The report received from Calgon is included as Appendix 9A of this Keystone Treatability Report. The results of the ACT indicate that for the gravity settled sample of site groundwater tested phenolics will be the limiting factor, followed by TOC, and finally the naphthalene. Carbon usage rates obtained by Calgon agree closely with those obtained by Keystone. The estimated carbon usage for a TOC influent of 58 ppm and an example treatment objective of 30 mg/l was 2.5 pounds per 1000 gallons of groundwater treated (Keystone's carbon isotherm estimate was 2.08

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pounds per 1000 gallons.) Calgon's carbon use estimate for naphthalene at a 0.5 ppm example treatment limit was 1 pound per 1000 gallons, (Keystone's was 0.85 pounds per 1000 gallons). Calgon's carbon use estimate for phenols at a 0.5 ppm example treatment limit was 2.75 pounds per 1000 gallons (Keystone's was 4.67 pounds per 1000 gallons.) The Calgon ACT was performed on an empty bed contact time of 15 minutes.

Soil Washing

Keystone performed bench scale soil washing testing using the principles of froth flotation aided by the addition of surfactants. A battery of screening tests were performed testing different combinations and amounts of surfactants, test conditions, number of wash cycles, etc., in order to optimize a soil washing procedure to effectively clean both surface and subsurface soil samples from area A-04 at the site.

The best three screening run tests were chosen for both the surface and subsurface soil samples. Three tests for each soil sample were run monitoring oil and grease, methylene chloride extractables, and percent solids. Parameter removal rates greater than 98% were seen for the subsurface soil samples tested, and greater than 95% removal rates for the surface sample. These screening tests utilized one 25 minute washing cycle, followed by a one minute rinse cycle, a 1:5 soil to water ratio, and pH adjustments using sodium hydroxide.

Based on the results of the screening run tests a final washing test was performed on each soil sample. The treatment indicator parameters used in the two final soil washing runs were oil and grease, methylene chloride extractables, and PAH. The high percent removals for oil and grease and methylene chloride extractables achieved in the screening runs were duplicated in the final runs with greater than 97% removals achieved in both tests. The PAH removal rate was over 99% in the subsurface soil sample and over 77% in the surface soil sample tested, as compared to the mean soil PAH concentration obtained from the statistical analysis of the six raw untreated soil samples tested.

Conditions of the final soil washing tests were: a 1:5 soil to water ratio, two 45 minute wash cycles, one ten minute rinse, pH adjustments using sodium hydroxide, and a total of approximately 0.04 wt % of surfactants used in each test.

Soil Bioreclamation (Soil Columns)

An eight week bench scale bioreclamation experiment was performed to evaluate the feasibility of treating South Calvalcade soils biologically on-site. This experiment simulated in situ conditions as closely as possible, and involved pumping site groundwater upflow through packed soil columns which were supplied the proper environmental conditions, nutrients and a microbial seed to enhance the biodegradation rate of organics present in the site soil. Effluent samples from the soil columns were sampled every two weeks. The soil and groundwater were sampled initially, as well as the final soil and groundwater after eight weeks of operation.

The effluent result from the control soil column contained an average naphthalene concentration of about 824 ug/l. The concentration of naphthalene solubilized off the site soil was consistent over the eight week study. The control column received only a tap water feed, and no nutrients or sludge seed were added. Therefore the PAH components present in the effluent were washed off the site soil in the column.

The anaerobic soil column received nutrients, sludge seed, and sodium nitrate as an electron acceptor for the anaerobic biological degradation process. The effluent PAH concentrations were much less, 78 percent less initially and 92 percent by the final effluent sampling. This decreasing PAH effluent concentration, along with nutrients and nitrate usage indicates that a microbiological population was established and was degrading the water soluble PAH's in the groundwater influent provided.

Similarly, the aerobic soil column achieved biodegradation of the PAH compounds present in the groundwater feed. Initial effluent PAH concentrations were reduced 56 percent from the influent and, final effluent PAH concentrations were reduced 78 percent. The lower molecular weight 2, and 3 ring PAH components were the ones primarily being degraded in the soil columns. This fact reflects the higher water solubility of these 2 and 3 ring compounds.

The groundwater feed for the soil columns contained 4242 ug/l total PAH initially, and decreased to 1201 ug/l by the end of the soil column study.

Soil results vary so widely that no conclusions were made concerning the performance of the soil columns with regards to treating the soil phase.

Slurry Reactors

As a part of the biological degradation work performed using site soil and groundwater samples, Keystone also performed testing using two biological slurry reactors. These slurry reactors, also called suspended growth biological reactors, each contained 56 wt % area A-04 subsurface soil and 44 wt % gravity settled groundwater to form a 2500 ml slurry. One slurry reactor was operated aerobically and one anaerobically, and in both, the soil was continually kept in suspension by an electric stirrer. The anaerobic reactor was supplied with a nitrogen gas blanket on top to maintain anaerobic conditions. The aerobic reactor was supplied humidified laboratory compressed air to maintain a dissolved oxygen concentration of at least 3 mg/l.

The aerobic reactor had several incidences of violent foaming upon the addition of air. A commercial antifoam was added to the aerobic reactor and it controlled the foaming for approximately one week, and then more had to be added. Approximately one-third of the initial water phase was lost due to this unexpected foaming problem, and tap water was added to make-up the reactor volume.

Both reactors were supplied nutrients (nitrogen and phosphorus) and additionally the anaerobic reactor was supplied nitrate. Test kit measurements in the laboratory of the water phase indicated a consistent daily usage of nutrients and nitrate.

The soil and water phases of each slurry reactor were separated and sampled at the end of four weeks for pH, percent solids, and PAH. The water phase PAH concentrations were decreased 66% and 88% for the aerobic and anaerobic reactors respectively. Specifically it was the lower molecular weight, 2 and 3 ring PAH compounds, which being more water soluble than the higher 4, 5 and 6 ring PAH components went into solution and were biodegraded by the microbial population in the slurry reactors. For example, naphthalene, a 2 ring PAH was over 99% removed, and carbazole a 2 ring PAH was greater than 97% removed in both aerobic and anaerobic reactors. The amount of biodegradation of PAH components achieved is

a function of many phenomenon. For example the adsorption/desorption characteristics of the site soil, the solubility of the PAH components in the groundwater, and the relative susceptibility to biodegradation of the PAH components. It appears that the rate limiting step in soil biodegradation work is the desorption of PAH from the soil. Once solubilized the PAH components can be biodegraded both aerobically and anaerobically.

Results from the soil phase of the slurry reactors were inconclusive, with the aerobic reactor soil PAH concentration being over 46% removed and the anaerobic reactor soil had an increase in PAH concentration, as compared to the mean soil PAH concentration calculated.

These results were based upon one final soil sample for PAH analyses for each slurry reactor only.

Activated Sludge Co-Treatability Study

The concept of treating contaminated groundwaters jointly with domestic sanitary wastewaters at a publicly owned treatment works (POTW) was tested in a separate project by Keystone in 1987, on a pilot plant scale. Specifically the groundwater contained chemicals from the coal and coal tar based family and was sampled from a former manufactured gas plant (MGP) site, where gas for lighting and heating was produced from coal or oil. A second groundwater, from a former coke plant site was also used in this pilot study. The coke plant site groundwater had higher concentrations of the chemicals of interest present than did either the MGP site, or does the South Calvalcade site groundwater. As such this coke plant groundwater served as a worse case scenario for evaluating the concept of co-treatability. A third control reactor was fed 100% POTW sanitary influent water and thus served as a baseline for comparison. The South Calvalcade site groundwater is most closely similar to the MGP site groundwater concentration.

Results from the co-treatability study support the feasibility of treating these types of groundwater jointly with domestic wastewaters at a POTW employing the activated sludge process.

The effluent water quality did not change as a result of adding the groundwaters in terms of: conventional, inorganic, volatile aromatics, and metals chemical parameters. In terms of total phenolics and total PAH, the coke plant site reactor showed slightly higher effluent concentrations. Even though some of the chemicals of interest were detected in the coke plant site reactor's effluent, the concentrations measured were below the Best Available Technology (BAT) treated discharge standards recently set for the organic chemicals industry.

Based on steady-state air monitoring results, the industrial site reactor was the only one of three tested which had any volatilization from the aeration tank of benzene, toluene, naphthalene, and acenaphthalene.

The metals concentration of the wasted activated sludge for all three units was the same. The coke plant reactor's sludge contained higher levels of PAH, total phenolics, and volatile aromatics than the other two reactors. The MGP site reactor's wasted sludge did not show any concentrations higher than in the control reactor's sludge.

In all three reactors, no change was seen in the number or diversity of microorganisms present in the mixed liquor taken originally from the POTW and used to seed the reactors.

Toxicity testing using the Microtox™ acute bioassay test showed all three effluents to be nontoxic to luminescent bacteria (the Microtox test organism), despite the coke plant site reactor's influent feed being toxic, based on the Microtox test.

Additionally, the results of this study show that the addition of a groundwater such as the South Calvalcade site groundwater used in Keystone's laboratory work will generally be below detection limits in the influent due to dilution alone, to even a small POTW, of one million gallons per day. The chemicals of interest present in the South Calvalcade site have been proven to be biologically degradable in an activated sludge treatment process. Included in Appendix A of this report to support this statement, are 19 actual cases from Keystones files, of successful applications of the activated sludge treatment process for the chemicals of interest present at the South Calvalcade site.

1.0 INTRODUCTION

This report presents the results of a treatability laboratory study performed by Keystone Environmental Resources, Inc. (Keystone) at its Monroeville Research Science and Technology Center. This study was designed to technically evaluate the feasibility of treating soils and water samples collected from a site formerly owned by the Koppers Company, Inc. This site is called the South Calvalcade site, located in Houston, Texas. A wood preserving plant was previously operated at this site, and coal tar, and creosote compounds were used in the process. Previous work has been done on characterizing soils and water present on the site by McBride-Ratcliff and Associates, Inc. geotechnical consultants in Houston, Texas. Keystone utilized this previous characterization work to guide in the selection of both soil and water samples which contained the chemicals of interest in elevated concentrations. By selecting these types of samples, the majority of the site chemicals of interest were present in the siol and water samples used for treatability evaluations.

2.0 STUDY OVERVIEW

Soil and water samples were collected by Keystone personnel on November 18, 1987 and returned for testing by Keystone's Analytical Division in Monroeville, Pennsylvania. Details of sample collection and handling are discussed in Section 3. Also presented in Section 3 is the list of the chemicals of interest along with the concentrations found in the selected site groundwater samples. Section 4 of this report presents the specific treatment technologies investigated, followed by their respective results. Included in section 4 is a section describing an activated sludge co-treatability study. This co-treatability is considered as a treatment alternative which is technically feasible for the South Calvalcade site groundwater.

3.0 SAMPLE COLLECTION

Water Samples

On November 18, 1987 Keystone personnel collected water samples from the South Calvalcade site for use in the treatability laboratory study. Two observation wells in the former process area of the site were sampled. This old process area was located on the southern end of the site. One well was OW-11, located near the eastern boundary, and one well was OW-10, located near the western boundary. Seven 55-gallon drums of water were collected in all, 4 from OW-11 and 3 from OW-10.

Keystone personnel collected an on-site composite sample from the seven drums collected from Wells OW-10 and OW-11, and returned it via 24 hour service to Monroeville for analyses of the site chemicals of interest. The drums of sample collected from OW-10 and OW-11 were returned to Keystone's Monroeville labs via truck. A composite sample of these drums was also taken on December 10, 1987 at Monroeville for the site chemicals of interest. This resampling at Monroeville was to reveal any changes which may have occurred over time by shipping, handling, and storage of the water sampled. This duplicate sampling also gives a more recent characterization of the water sample to be used in the laboratory testing.

Results

Table 3-1 lists the chemicals of interest for the South Calvalcade site work as well as their concentrations in both the on-site and Monroeville composite samples. The last column of Table 3-1 presents the percent change between the on-site sample and the Monroeville sample taken approximately 3 weeks later. Generally, the results from both samplings are similar, i.e. the same orders of magnitude for both. Individual fluctuations occur, as would be expected between separate sampling events. The individual PAH component results can be found in Appendix 1 and Appendix 2 which presents all the data in its raw format as received from the laboratory. Some of the variation between samples can be explained by viewing the raw data in the appendices. For example, total PAH varies over 45% between sampling events. A slug of naphthalene may have ben sampled at Monroeville, as the naphthalene concentration increased 3 times from the initial sampling concentration. Therefore, the resultant increase for total PAH is seen. Another point worth noting is that there

TABLE 3-1

COMPARISON OF ON-SITE COMPOSITE SAMPLE TO THE MONROEVILLE COMPOSITE SAMPLE (RESULTS IN MG/L)

Parameter (mg/l)	On-Site Sample 11/18/87	Monroeville Sample 12/10/87	% Change from On-Site Sample
Biological Oxygen Demand (BOD)	325	255	-21.5
Chemical Oxygen Demand (COD)	580	768	+32.4
Oil and Grease (O&G)	113	144	+27.4
Pentachlorophenol (PCP)	-	0.0018	-
Total Kjeldahl Nitrogen (TKN)	3.59	3.10	-13.6
Total Organic Carbon (TOC)	63.4	59.8	-5.7
Total Phosphate (PO_4)	<0.100	0.176	+76
pH (standard units)	7.2	7.4	+2.8
Methylene Chloride Extractables	-	253	-
Total Recoverable Phenolics (as Phenol)	8.31	7.82	-5.9
Total Polynuclear Aromatic Hydrocarbons (PAHs)	71.4	39.2	-45.1
Arsenic (As)	0.0117	0.0154	+31.6
Lead (Pb)	0.0062	<0.005	-19.4

are only two sets of data points, hence higher percent differences may be expected than if there were many more data points to be averaged.

The Monroeville water sampling included analyzing for pentachlorophenol to ensure that this wood treating compound was not present. (The previously reported results in the Remedial Investigation (RI) document had not shown this chemical compound to be present on the site). The result of the analysis from Keystone shows a concentration of 00018 mg/L in Table 3-1. This concentration is essentially at the detection limit of 0.001 mg/L (1 ug/L), and is, therefore, not considered as a relevant chemical of interest for the remainder of the laboratory study.

Figure 3.1 presents a map of the site and the approximate locations of Well OW-10 and OW-11, as well as the approximate soil sampling locations.

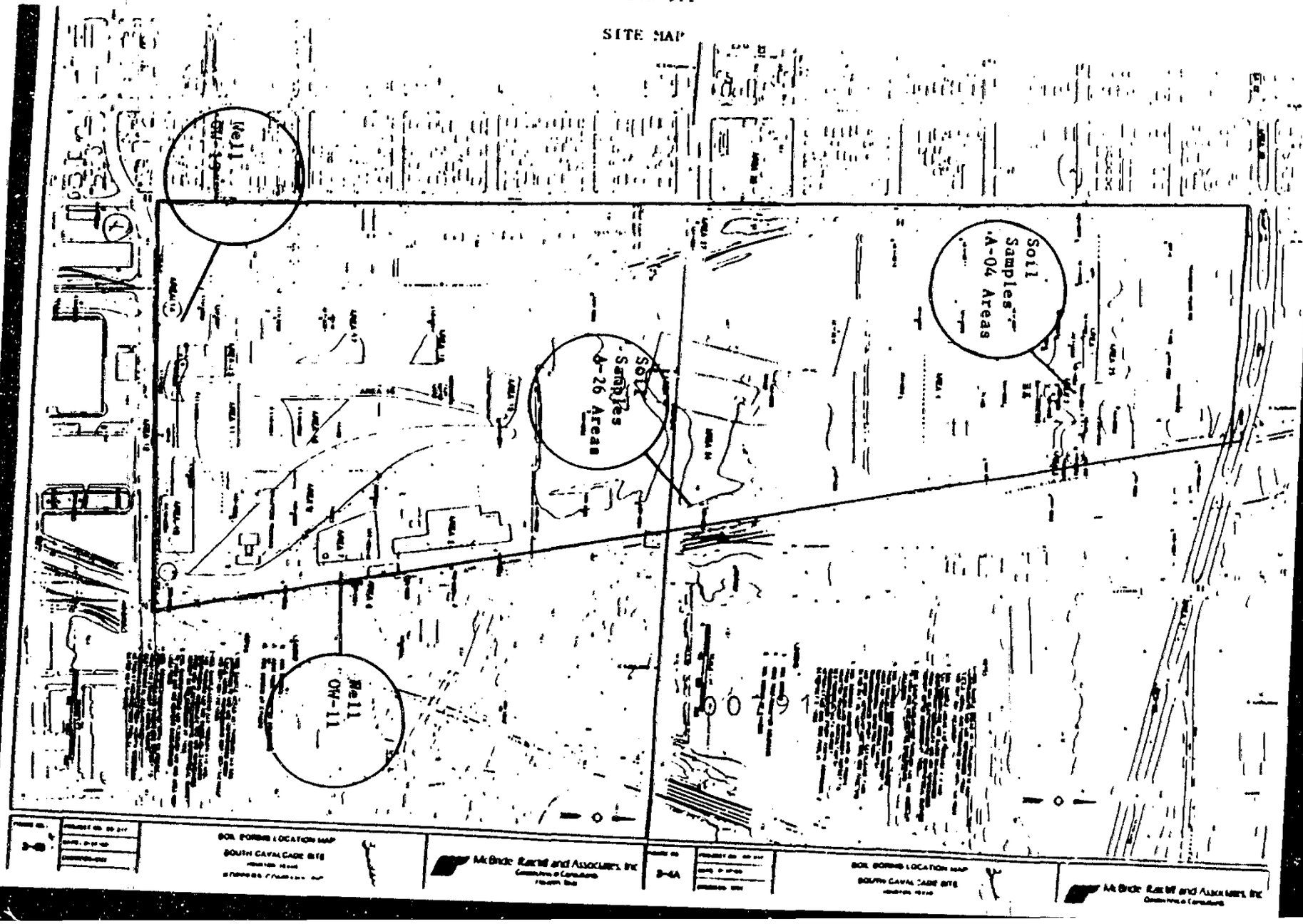
Soil Samples

Figure 3.1 is a map showing the site and the approximate sampling locations for the soil samples collected by Keystone personnel on November 18, 1987. A total of five 5-gallon buckets of site soil were collected by hand and returned via truck to Monroeville for use in testing. Two general areas were selected for soil collection; (1) area A-04 an old dump area which is believed to have been a creosote dumping area, and area A-26 in the northern portion of the site which had strong fuel oil smells in the soil. Three buckets of soil were taken from area A-04 between soil borings A04-SB01 and A-04-SB02, two at a depth of 10 to 11 feet deep, and one bucket from the surface to 1 foot depth. The surface soil sample was a dark brown loam with a coal tar chemical odor present. The sample had very little rocks or debris mixed with it. The 10-11 foot subsurface soil sample from area A-04 had a sand or silty sand consistency with dark oily contamination present which stained the sand darker. The subsurface soil samples received were sandy and had a strong coal tar type chemical odor, and about 1/2 inch of standing water on top. The three soil samples from area A-04 (the surface and subsurface samples) were the soils used in the laboratory testing.

Two 5-gallon buckets of subsurface soil were collected from area A-26 southwest of soil boring A26-SB05. The consistency of the A-26 soil sample was a hard packed sand, with a small amount of milky white standing water. The two sandy soil samples

FIGURE 3.1

SITE MAP



received were odorless and appeared clean, and were not used for any sampling or testing in this laboratory work.

The three soil samples which were used in testing (from area A-04) were treated as two samples. Both of the subsurface samples were composited and mixed well and were used in all subsequent soil experiments. The surface soil was kept separate, and was used in one experiment only.

The following section describes the specific testing programs performed by Keystone on the soil and water samples collected from the South Calvalcade site.

4.0 TREATMENT TECHNOLOGIES

4.1 Oil/Water Separation

Upon inspection of the seven drums of groundwater at the research center in Monroeville, it was found that the water settled very clear, with generally, a small oil sheen on top and on the bottom of the drums. For this reason it was decided to evaluate simple gravity settling, as well as polymer addition in standard jar testing for oil/water separation. The physical separation testing will be described first followed by the jar testing experiments.

A 4-gallon mixed composite sample from the seven drums was taken and placed into a 5-gallon glass jar. This sample was allowed to sit undisturbed for 24 hours and observations were made. A definite clearing of the water was noticed with an oil sheen on top and a heavy 1/2" sludge layer which settled onto the bottom. Samples of the clear supernatant were withdrawn from the middle portion of the jug and submitted for analyses. The results of these analyses are presented in Appendix 3.

A well mixed composite sample was also used in the polymer treatment jar testing experiments at Monroeville. A composite sample was taken from the seven refrigerated drums and was allowed to warm to room temperature before testing began. Polymers were screened at varying dosages in an attempt to find a polymer which would successfully flocculate the oil phase out of the water and into a stable sludge. The best polymer combinations found in this testing were:

Amerfloc 10 @ 300 ppm
Amerfloc 5260 @ 4 ppm
and
Amerfloc 10 @ 300 ppm
Amerfloc 5270 @ 4 ppm

These polymers are all Drew Chemical Company products. Amerfloc 10 is a cationic polymer and Amerfloc 5260 and 5270 are anionic polymers. Both combinations worked on the South Calvalcade groundwater sample, generating a large heavy floc which settled quickly into a stable sludge. The resultant supernatant was clear and relatively solids free.

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The supernatant phase of these jar tests were submitted for analyses by Keystone. The results of these analyses are presented in Appendix 4. (The abbreviation SC stands for South Calvalcade, and RW means raw untreated groundwater). Test #1 used the anionic polymer 5260 while Test #2 used 5270. The difference between the two anionic polymers is that 5270 has a slightly stronger anionic charge, and is, therefore, more expensive than 5260.

The final jar tests from which the samples were taken, used a total volume of 2500 mls of composited site groundwater. From each test the total amount of sludge collected was 28 mls. On a volume basis the wet sludge produced for every 1000 gallons of groundwater polymer treated, is 11.2 gallons or 1.12%. This corresponds to a sludge generation of roughly 0.07 pounds of (dry weight) sludge produced per 1000 gallons of water polymer treated, from each polymer combination. This resultant sludge was too dilute, and too low in creosote oil concentration to make a direct product recovery possible from this sludge alone. (As per visual inspection by the Koppers Company's Technical Service - Tar and Wood Sector laboratory.)

Table 4-1 presents a comparison between the results of samples generated by polymer treatment and by physical separation only. These results are in turn compared to the raw untreated composite sample of groundwater collected at Monroeville on December 10, 1987, shortly after the water shipment arrived. Percent removals from the untreated groundwater concentration levels are calculated and presented. As can be seen in Table 4-1 there was little added percent removal gained from the addition of polymers. In fact polymers added some total organic carbon to the water. The high removal rates achieved from physical separation alone made the addition of chemical polymers unnecessary for oil/water separation at this site groundwater sample. If the groundwater sampled would change, however, possibly becoming more concentrated in oil and grease type compounds, for example, the information on which polymers to use and at what concentration, has been generated, as well as one sludge generation estimate.

Based on the results of the oil/water separation work, the decision was made by Keystone to use gravity settling alone to generate relatively oil and solids free supernatant for use in all subsequent treatability testing experiments. The procedure which was followed was to siphon off an equal amount of clear supernatant from

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TABLE 4-1

COMPARISON OF POLYMER TREATMENT VERSUS PHYSICAL SEPARATION
(RESULTS IN MG/L)

	MSTC Raw Composite Sample 12/10/87	Polymer Treated Supernatent Sample 12/31/87	% Removal (from raw water)	Physical Separation Sample 12/14/87	% Removal (from raw water)
Methylene Chloride Extractables	253	54	78.7	75.0	70.4
Oil and Grease	144	13.6	90.6	19.9	86.2
Total Organic Carbon	59.8	59.6	0.3	60.5	(*)
Phenolics (4AAP)	7.82	-	-	7.72	1.3
Total PAH[1]	39.225	-	-	10.538	73.1

[1]Total PAH represents total polynuclear aromatic hydrocarbons.
(*)Indicates that parameter has increased in concentration.

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each of the seven refrigerated drums into one composite drum, which was allowed to warm to room temperature before the water was used in any laboratory testing.

4.2 UV/Oxidation

Introduction

Chemical oxidation testing using ozone, in conjunction with photooxidation using ultraviolet light was performed on a bench-scale by Keystone on the groundwater sample from the site. The ozone/UV unit used was developed by Ultrox International, Inc. This unit is comprised of an ozone generator along with a three liter stainless steel reaction vessel equipped with an ultraviolet light. Ozone is introduced into the reaction vessel through a gas sparger on the bottom, at a rate sufficient to achieve complete mixing. The ozone concentration in the gas stream to the reaction vessel was maintained at approximately 2% by volume. This 2% is about the maximum achieved in full-scale applications using a compressed air feed. Off-gas from the unit was periodically monitored for residual ozone concentration for determination of the ozone usage efficiency. This efficiency is defined as the ratio of ozone used in the reaction, compared to the total ozone applied to the sample.

Procedure

In order to evaluated how effective UV/ozone treatment was on this particular groundwater, Keystone first performed a UV/ozone screening run. In this screening run the groundwater sample was subjected to UV/ozone treatment for a total of 30 minutes, with samples withdrawn at times 0, 1, 3, 5, 7, 10, 15, 20, and 30 minutes. These samples were analyzed for some parameters which served as indicators of treatment for this water, (pH, TOC, Phenol and Naphthalene). Comparisons were made between the level of treatment attained versus amount of ozone applied. Based on the results from the screening run, an optimum ozone dosage was selected.

A final sampling UV/ozone run was then performed at the optimum dosage chosen. Enough batch runs were performed to generate water samples for the whole list of site chemicals of interest. The results of these UV/ozone experiments are presented next.

TABLE 4-3a

ACTIVATED CARBON

ACT RESULTS

		TOC	Phenols (4 AAP)	Naphthalene
1)	Anticipated Initial Groundwater Concentrations	63 ppm	8 ppm	35 ppm
2)	Measured Initial Groundwater Concentrations	58 ppm	5.3 ppm	0.335 ppm
3)	Example Treatment Objectives	30 ppm	0.5 ppm	0.5 ppm
4)	Anticipated Activated Carbon Usage (2 vessels in series)	2.5 #/m(1)	2.75 #/m	1.0 #/m
5)	Keystone's Activated Carbon Isotherm Test Results	2.08 #/m	4.67 #/m	0.85 #/m
6)	Keystone's Measured Initial Groundwater Concentrations	56 ppm	7.45 ppm	2.74 ppm

(1) #/m is pounds of activated carbon per 1000 gallons of site groundwater treated.

Screening Run

The screening run results are presented in Appendix 5, as received from Keystone's laboratory. These results are presented graphically in Figures 4.2-1 and 4.2-2 for the phenol and naphthalene test results, respectively. The plot in Figure 4.2-1 shows that at the 285 mg/l ozone dosage (time 10 minutes), the slope of the line changes. At this point diminishing returns are seen for applying more ozone to remove phenol, i.e. the slope of this line is less. At this point in the experiment the available ozone then begins attacking the naphthalene more vigorously, as can be seen in Figure 4.2-2. Therefore, the optimum ozone/UV dosage chosen for use in the final sampling runs was 285 mg/l (10 minutes). The screening run results after ten minutes of ozone/UV treatment achieved an effluent concentration of 0.053 mg/l phenol, a 98.9% reduction from the influent concentration.

The first order decay rate constants (K) were calculated from the screening run results for both phenol and naphthalene. These K rate constants are:

Phenol = -0.0077
Naphthalene = -0.0046

Generating the K rate constants is a method used to quantify treatment performance and to enable relative comparisons to be made between ozone/UV treatment of different wastewaters. A negative K rate indicates that reduction has occurred during the test for the monitored indicator parameter, a zero value indicates no reduction, and a positive K rate indicates an increase in concentration of the measured parameter. The lower the K rate constant number is, the more reduction of the monitored parameter in the experiment.

The method used to calculate the K rate constant was to plot the screening run data with a computer using a least squares regression technique. The slope of the line generated is the K rate constant. Appendix 6 contains the K rate calculation printouts for both phenol and naphthalene. The X value listed on the printouts is the ozone applied, in mg/l. The Y value is the natural logarithm (ln) of the concentration of each parameter monitored, in mg/l for phenol and ug/l for naphthalene. A 95% confidence interval was used throughout in the calculations.

FIGURE 4.2 - 1

SOUTH CALVALCADE

OZONE/UV SCREENING RUN

PHENOL 4AAP

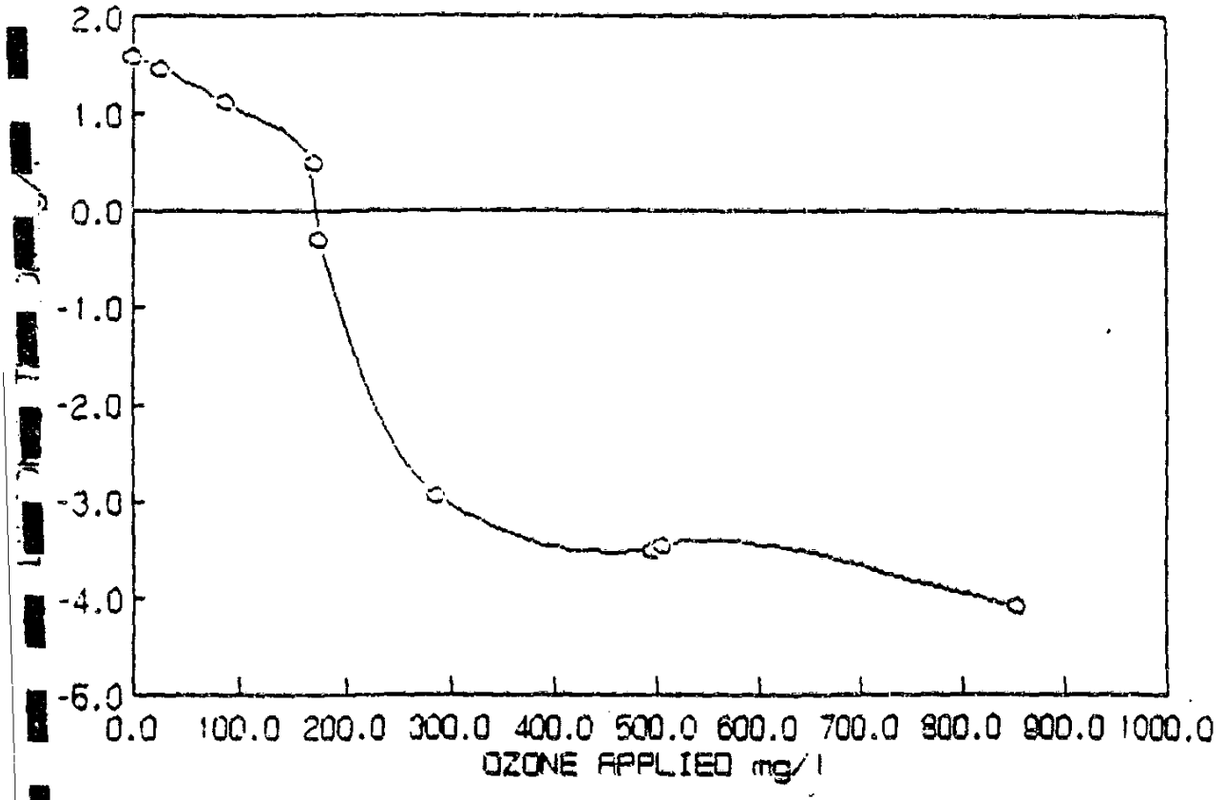

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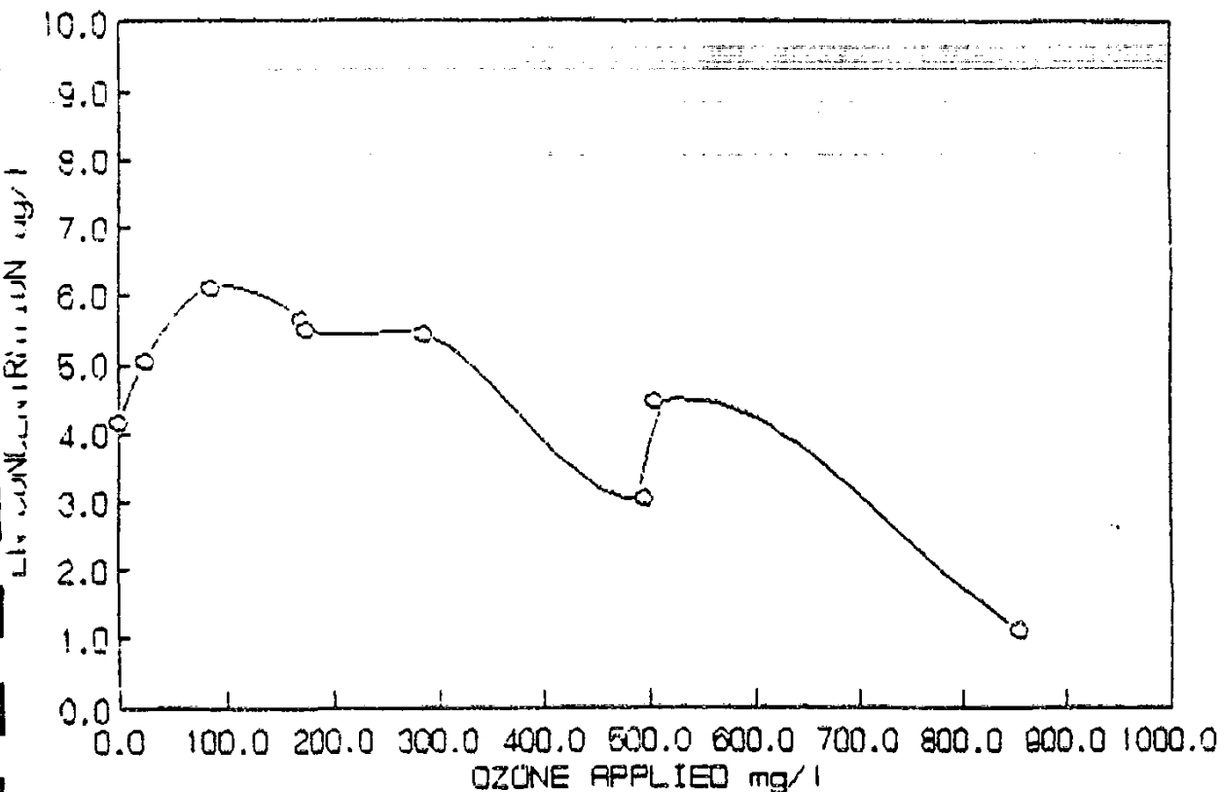
Figure 4.2 - 2

SOUTH CALVALCADE

OZONE/UV SCREENING RUN

NAPHTHALENE



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The average ozone utilization efficiency achieved in the screening run test was 59 percent.

Final Run

A final ozone/UV sampling run was performed using site groundwater, at a 285 mg/l ozone dosage, (a 10 minute ozone/UV exposure time). The site chemicals of interest in the ozone/uv treated effluent were sampled for and analyzed at Keystone's Monroeville laboratories. The results of these sample analyses are presented in Appendix 7.

The final ozone/UV treatment tests achieved an average ozone utilization efficiency of 57 percent. This efficiency agrees closely with the 59 percent efficiency obtained in the screening run test. This ozone efficiency is a measure of how much ozone is used in the reaction, versus the total amount of ozone that is applied into the reaction vessel.

The phenols (4-AAP) analysis showed a 98.4 percent reduction in the treated effluent. This agrees closely with the screening run test result which achieved a 98.9 percent removal of phenols (4-AAP) from the influent concentration, at a 10 minute contact time.

The pH of the ozone/UV teated water was 6.4, slightly less than the measured influent groundwater pH of 6.7.

The ozone/UV treatment had no effect on the remaining conventional pollutants monitored, i.e. COD, BOD, TKN, PO4, TOC, and oil and grease.

The metals were likewise unaffected by the ozone/UV treatment employed.

Total polynuclear aromatic hydrocarbon (PAH) removal achieved was 52.5 percent of the influent groundwater concentration. Table 4-2 presents the individual PAH components and how they were affected by ozone/UV treatment. A general trend of decreasing percent removal is seen as the number of rings (molecular weight)

TABLE 4-2
FINAL OZONE/UV TEST
PAH RESULTS (in ug/l)

PAH Component	# of Rings(1)	Water Solubility (ug/l)	Influent Concentration	Effluent Concentration	Percent Removal
carbazole	2	-	<2.00	<2.00	-
naphthalene	2	31700	<2.00	<2.00	-
acenaphthene	3	3930	56.3	30.5	45.8
acenahthylene	3	-	3.03	<2.00	>33.9
anthracene	3	73	12.0	4.48	62.7
fluorene	3	1980	18.6	7.23	61.1
phenanthrene	3	1290	66.1	32.3	51.1
benzO (A) anthracene	4	14	45.1	6.93	84.6
chrysene	4	2	43.5	13.2	69.7
fluoranthene	4	260	101.0	57.6	42.9
pyrene	4	135	111.0	54.8	50.6
benzo (K) fluoranthene	5	-	8.1	4.27	47.3
benzo (A) pyrene	5	3.8	14.4	6.20	56.9
benzo (b) fluoranthene	5	-	21.3	11.1	47.9
dibenz (A,H) anthracene	5	2.49	24.9	15.4	38.1
indeno (1,2,3-cd) pyrene	6	-	11.9	8.16	31.4
benzo (G,H,I) perylene	6	0.26	16.8	11.1	33.9
TOTAL PAH	-	-	554.03	263.27	52.5

(1) # of rings refers to the number of benzene rings present in each PAH component

increases, and the PAH solubility decreases, as would be expected. The higher ring PAH's are more resistant to degradation than are the lower ring components.

Also included in Appendix 7 are the results of Microtox^{TM} bioassay testing on site groundwater before and after ozone/UV treatment. Microtox measures sample acute toxicity by utilizing salt water luminescent bacteria as the test organisms. Included in Appendix 7 Microtox results are the initial standards tested, followed by the ozone/UV effluent, and influent groundwater results respectively. All tests were run in duplicate and show close agreement between duplicate test results. The Microtox test results are reported in effective concentrations (EC). The EC values reported are for 20, 50 and 80 percent, meaning a result that effects 20, 50 and 80 percent of the test population. In this case, the effect is a light loss by the luminescent bacteria as an indirect measure of toxicity. An EC20 = 2.5 for example, means that it required 2.5 percent of the groundwater sample to inhibit 20 percent of the bacterial light emission. The lower the EC percentage obtained, the higher the sample's toxicity (to marine luminescent bacteria), or stated in another way, less sample was needed to induce the chosen effect (i.e. either 20, 50 or 80 inhibition of light production).

The exposure times used were the standard 5 and 15 minute tests employed in Microtox. Using two exposure times (of bacteria to sample) often reveal information on the nature of the toxicity of a sample, or how its exerted. The standard test temperature utilized was 15^{o}C.

Table 4-3 presents the results of the Microtox bioassay testing performed on site groundwater before and after treatment by ozone/UV. The EC50 is the most commonly used measure in reporting effective concentrations. As can be seen from the EC50 results listed in Table 4-3, the influent was very toxic. After exposure to ozone/UV treatment the effluent was measured as toxic. The ozone/UV treatment decreased the Microtox EC50 toxicity measured by about 8 percent. The fact that the 15 minute tests showed only slightly higher toxicity than did the 5 minute exposure test, indicates that the majority of the toxicity was exerted quickly, and that no recovery from it was evident by the 15 minute exposure time tested.

TABLE 4-3
MICROTOX RESULTS
OZONE/UV INFLUENT AND EFFLUENT SAMPLES

Sample	Concentration Measured	5 Minutes	5 Minutes Duplicate	15 Minutes	15 Minutes Duplicate
Influent	EC20	0.590	0.625	0.500	0.550
	EC50	2.477	2.369	2.091	2.140
	EC80	10.390	8.988	8.746	8.319
Effluent	EC20	2.342	3.372	2.190	2.579
	EC50	10.844	11.737	9.361	8.704
	EC80	50.209	40.857	40.010	29.380

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EXAMPLE MICROTOX INTERPRETATION SCALES

Toxicity Rating	EC50	EC20
4-Very Toxic	<10%	<4%
3-Toxic	>10% to 50%	>4% to 20%
2-Mildly Toxic	>50% to 75%	>20% to 30%
1-Slightly Toxic	>75% to 100%	>30% to 40%
0-Non Toxic	>100%	>40%

4.3 Activated Carbon

Introduction

Keystone performed bench-scale testing using isotherms to evaluate the feasibility of treating site groundwater with activated carbon. In addition, Keystone subcontracted the Calgon Corporation to perform their accelerated carbon testing (ACT) program on a sample of site groundwater.

Procedure

The isotherm testing utilized Calgon's Filtrasorb F-300 granular activated carbon, pulverized so that 95 wt% passed through a 325 mesh screen. The standard isotherm test performed used 12 different weight ratios of activated carbon per 100 mls of groundwater; 0.005, 0.01, 0.025, 0.05, 0.1, 0.2, 0.5, 1.0, 2.5, 5, 10, and 20 grams. Additionally, one test with no carbon added served as the control test. These carbon/groundwater slurries were contacted for 1 hour, and then the liquid was separated from the carbon by filtering. The liquid phase was submitted for analyses for; TOC, phenol, and pH, by Keystone's Monroeville laboratory.

A liquid phase isotherm shows the distribution of adsorbate (that which is adsorbable) between the adsorbed phase and the solution phase at equilibrium concentrations. Form this isotherm test a carbon usage estimation can be obtained. This estimate tends to be a "best case" scenario i.e. in most carbon column systems the carbon usage will be greater than that predicted from isotherm testing. However, the isotherm test is a valid method for quickly testing the feasibility of using a particular activated carbon for treating a specific wastewater.

For a more accurate estimate of carbon usage, carbon column testing is normally performed after carbon isotherms. Keystone subcontracted this carbon column testing to the Calgon Corporation's Pittsburgh laboratory, which performed their Accelerated Column Testing (ACT) program on a sample of gravity settled site groundwater.

Isotherm Testing

Appendix 8 lists the sample results obtained in the isotherm testing performed by Keystone. The abbreviation CI represents carbon isotherm and the weights listed are the amounts of F-300 pulverized activated carbon per 100 mls of groundwater, used in testing. Appendix 9 presents the plots of the isotherm data obtained. Table 9-1 in Appendix 9 is the worksheet used to manipulate the isotherm results into the form needed to plot the data. A logarithm plot of concentration of parameter in solution (c), at equilibrium, versus the total weight of parameter adsorbed per unit weight of carbon (X/M) is found in Appendix 9 for each monitored parameter. A straight arithmetic plot of the pH is also provided in Appendix 9. An equation which describes each line drawn in the plots is also given. This equation is generated by a computer program which describes the data by using a linear regression technique. By solving this equation for the influent concentration of the monitored parameter, an estimate of the maximum adsorption capacity for that carbon, and that wastewater is obtained.

The equation from the isotherm plot for naphthalene gave a maximum adsorption capacity of 27.0 mg naphthalene per gram of F-300 carbon used. The plot is straight line, but only contained three usable points, the minimum amount for a linear regression calculation. Based upon the influent concentration of 2.740 mg/l naphthalene, the estimated carbon usage rate is 0.85 pounds per 1000 gallons of groundwater treated.

The equation from the isotherm plot for phenol adsorption gave a maximum adsorption capacity of 13.3 mg phenol per gram of F-300 carbon used. The plot of the data was straight-line and showed small variation from the line drawn. Based upon the influent concentration of 7.45 mg/l phenol, the estimated carbon usage rate is 4.67 pounds per 1000 gallons of groundwater treated.

The first TOC plot presented in Appendix 9 includes all 12 data points generated in the TOC isotherm test. As can be seen in the raw data, listed in Table 9-1 in Appendix 8, the TOC concentration in solution levels off and remains near 4 mg/l. This concentration is approaching the detection limit of 1 mg/l for the TOC analysis. The plot of this data shows a two stage effect, where no additional TOC is adsorbed after the 5th data point plotted, despite increased carbon dosages applied.

A more accurate interpretation of the TOC isotherm is to replot the data using only the first 5 data points. This plot is presented next in Appendix 9, and results in a good fit, straight line plot. From the equation generated which describes this second TOC plot, the maximum adsorption capacity is 224 mg TOC per gram of F-300 carbon used. Based upon the influent TOC concentration of 56 mg/l, the estimated carbon usage rate is 2.08 pounds per 1000 gallons of groundwater treated.

ACT Results

The report issued from the Calgon Corporation presenting the results of their Accelerated Column Test (ACT) is included as Appendix 9A. The ACT uses activated carbon and simulates a carbon column system. The ACT was performed at the Calgon Corporation's Pittsburgh, Pennsylvania laboratory on a sample of gravity settled site groundwater supplied by Keystone.

Since no projected flow estimate of pumped groundwater or permit limits for the South Calvalcade site were available at the time of performing the treatability work, Keystone specified the following conditions to Calgon for the ACT: a 15 minute empty bed contact time, the treatment indicator parameters and example treatment objectives of; TOC = 30 ppm, phenols (4AAP) = 0.5 ppm, and naphthalene = 0.5 ppm.

Table 4-3a presents a summary of the ACT results along with Keystone's isotherm test results for comparison. As can be seen, the results from the ACT duplicate those from the isotherm tests, with only the phenols (4AAP) estimates differing slightly. The naphthalene concentration of the site groundwater was much lower than was anticipated in the ACT, based upon Keystone's on-site and Monroeville samplings. The on-site composite groundwater sample contained 35.6 ppm of naphthalene, the Monroeville sampling about 3 weeks later contained 11.6 ppm of naphthalene, and the ACT sample contained only 0.335 ppm of naphthalene. Obviously, the naphthalene present in the wells initially on site was being volatilized out of solution with the passing of time and the additional mixing by sample handling. (The Henry's law constant at 25°C for naphthalene is 4.60×10^{-4} ATM-M^3/MOLE).

The results of the ACT indicate that the phenolics will be the limiting factor (for carbon adsorption), followed by TOC, and finally the naphthalene.

Appendix 9a contains information from the Calgon Corporation on several carbon adsorption treatment systems that they offer along with the estimated carbon use rate for the site groundwater tested. Breakthrough curves for the specified treatment indicator parameters are also given in the Calgon report.

4.4 Soil Studies

The following five subsections detail the experiments performed by Keystone on the soil samples collected from the South Calvalcade site. The soil used in this testing was surface and subsurface soil collected from area A-04. The two pails of subsurface soil were composited, mixed and sieved through a 1/4 inch screen. The soil was sandy in texture, and less than 2% was retained on the screen. A sieve analysis on this subsurface soil composite is presented in Table 4-4, and graphically in Figure 4.4-1. As can be seen from Figure 4.4-1, this soil sample was sand.

An estimate of the porosity of the composited A-04 area soil was made by using a constant head permeability test. Soils found in situ have widely different permeabilities along their stratification, and perpendicular to it. Therefore, the results obtained on disturbed samples often are not accurate of site specific, in situ conditions. However, the permeability measured in the laboratory did, in fact, agree fairly well with previously reported permeability values of site soils. The permeability measured in the lab was 1.07×10^{-4} cm/second. The horizontal permeability given in the Remedial Investigation (RI) document was 1×10^{-3} cm/second. A general permeability estimate for this site suggested by Keystone's Hydrogeology Department was 1×10^{-5} cm/second. The result from this permeability test is used in a soil column experiment, which is described later in Section 4.7.

During the course of this soil treatability work six separate samples of raw composited site soil from area A-04, surface and subsurface samples, were analyzed for polynuclear aromatic hydrocarbons (PAH). Due to the heterogeneous nature of a soil sample matrix the PAH results showed wide variations, between 900 to 8,300 mg/kg, on a dry weight basis. This is common when analyzing soils which have

TABLE 4-4

SIEVE ANALYSIS

SOIL SAMPLE Composite #2 & #3

LOCATION South Calvalcade

BORING NO _____ SAMPLE DEPTH _____

SAMPLE NO _____

SPECIFIC GRAVITY, G_s _____

SOIL SAMPLE WEIGHT

CONTAINER NO _____

WT CONTAINER + DRY SOIL IN g 871.3

WT CONTAINER IN g 371.2

WT DRY SOIL, W_s, IN g 500.1 g

TEST NO _____

DATE 1/5/88

TESTED BY KJG

SIEVE NO	SIEVE OPENING IN mm or um	WT SIEVE IN g	WT SIEVE + SOIL IN g	WT SOIL RETAINED IN g	PERCENT RETAINED	CUMULATIVE PERCENT RETAINED	PERCENT FINER
10	2 mm	444.5	444.9	.4	.080	.080	99.92
20	850 mm	346.4	375.4	29.0	5.795	5.875	94.125
40	425 u	315.9	393.5	77.6	15.506	21.383	78.617
60	250 u	379.7	439.2	59.5	11.890	33.273	66.727
140	106 u	274.1	556.8	282.7	56.495	89.768	10.232
200	75 u	277.7	322.7	45.0	8.993	98.761	1.239
PAN	-	377.9	384.1	6.2	1.239	100.000	0
				500.4			

REMARKS *

4-10a

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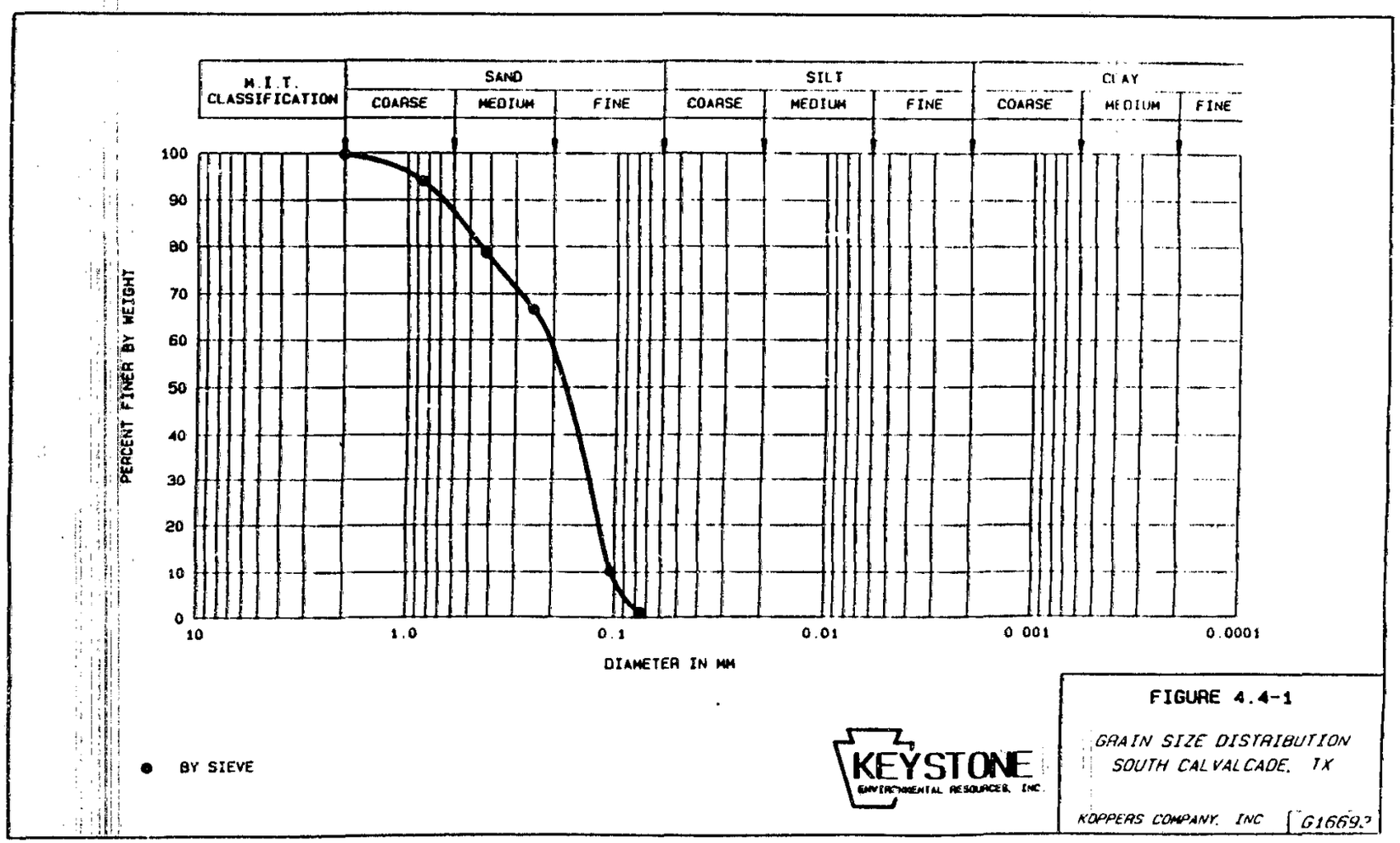

FIGURE 4.4-1

GRAIN SIZE DISTRIBUTION
SOUTH CALVALCADE, TX

KOPPERS COMPANY, INC [G1669.2]

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elevated concentrations of PAH components despite the best efforts to obtain, and then analyze representative well mixed samples.

Five of the soil samples used for testing in this South Calvalcade work were taken from two 5 gallon pails of subsurface soil which were well mixed and then composited. One surface soil sample was taken from a well mixed 5 gallon bucket. Care was exercised throughout all experiments to take subsamples from different areas of the soil portions taken for testing. The analysts in Keystone's laboratory dumped out the soil samples submitted, mixed them, took subsamples and composited them, for the final soil samples used in the chemical analyses. The soils were all analyzed for percent solids as well as PAH to enable direct comparisons to be made between results of separate soil samples. The variations seen in the PAH results are due primarily to the heterogeneous nature of a soil matrix. Unlike a water sample which is homogeneous, a spoonful of soil sampled inches away from a clean soil sample may contain gross amounts of the chemical(s) monitored, i.e. a soil particle may be coated with creosote oil.

In order to most accurately represent the PAH concentration found in soil samples taken from area A-04, a statistical analysis was performed on the six sets of PAH data generated on the raw untreated soil samples (five subsurface and one surface soil sample). Table 4-4a presents the results of this statistical analysis of the PAH data. The mean PAH concentration obtained was 3747.49 mg/kg on a dry weight basis. The 95% CI column is the 95% confidence interval for the mean value. The actual PAH analytical results are reported in ug/kg by the laboratory and were converted to mg/kg due to spatial constraints of the statistical computer program.

The raw untreated soil PAH concentration for all of the treatability work performed on site soil samples will be assumed to be the mean concentration value of 3,747,490 ug/kg on a dry weight basis.

When mixed with soils, sediments or sands, contaminant materials are usually held in the solid phase by one or more physical-chemical phenomena. For example this holding of the contaminant can be the result of entrapment, adsorption on the mineral surfaces, or chemical reaction with the solid surfaces.

TABLE 4-4a

SOUTH CAVALCADE
STATISTICAL SUMMARY for PAH DATA

Parameters	# OF OBVS		MEAN	+/- CI	STD	95% CI LOWER	95% CI UPPER	GMEAN	GSTD	MIN	MAX	90% LT VALUE
Acenaphthene	6	0	776.51	449.83	428.57	326.68	1226.35	660.15	1.99	192.55	1494.25	1566.29
Acenaphthylene	4	2	76.77	142.85	89.78	.00	221.61	13.79	16.49	1.16	164.35	471.19
Anthracene	6	0	139.02	156.08	148.70	.00	295.09	65.63	4.52	8.36	344.83	439.33
Benzo(a)anthracene	6	0	110.94	123.90	118.05	.00	234.84	57.20	3.83	14.65	270.11	310.92
Benzo(a)pyrene	6	0	35.74	34.28	32.66	1.47	70.02	18.27	4.71	1.38	80.21	128.64
Benzo(b)fluoranthene	6	0	56.96	46.54	44.34	10.43	103.50	40.95	2.56	14.25	107.93	134.11
Benzo(g,h,i)perylene	6	0	46.33	40.69	38.77	5.64	87.02	32.47	2.63	10.40	104.97	109.79
Benzo(k)fluoranthene	6	0	20.75	18.53	17.66	2.22	39.29	13.80	2.86	4.49	42.94	51.95
Chrysene	6	0	104.18	120.17	114.49	.00	224.35	52.53	3.88	12.57	258.62	290.35
Dibenz(ah)anthracene	6	0	52.85	41.54	39.57	11.31	94.38	39.14	2.52	9.96	118.06	125.20
Fluoranthene	6	0	338.61	371.05	353.51	.00	709.66	171.29	4.08	28.37	817.24	1007.33
Fluorene	6	0	257.75	276.77	263.69	.00	534.52	144.24	3.48	40.60	609.20	694.30
Indeno(123-cd)pyrene	6	0	27.54	19.69	18.76	7.85	47.23	20.51	2.54	5.15	48.09	66.55
Phenanthrene	6	0	681.18	821.82	782.97	.00	1503.00	268.21	5.51	37.26	1701.39	2300.82
Pyrene	4	0	486.01	414.40	260.46	71.61	900.41	407.99	2.16	133.50	706.90	1078.17
Carbazole	6	0	80.43	73.91	70.41	6.52	154.34	45.96	3.77	9.31	174.57	244.70
Naphthalene	5	0	756.89	******	878.27	.00	1847.23	326.95	4.82	52.48	1886.57	2374.07
Total PAH	6	0	3747.49	******	3471.65	103.62	7391.36	2448.69	2.82	938.58	8290.69	9054.58
Date Collected	0	0	0.	0.	.00	0.	0.	.00	.00	.00	0.	0.

All values were used in the statistics

All results are calculated on a dry weight basis.
All data is reported in mg/Kg unless otherwise noted.

****** The confidence interval for naphthalene = ±1090.34
****** The confidence interval for total PAH = ±3643.87

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Entrapment occurs when the contaminant exists in such large quantities that it exceeds its solubility and has taken up the available adsorption sites so that it exists as a separate phase. This inner-granular material is simply trapped by the solid particles and can be removed by physical beneficiation equipment, i.e. soil washing using froth flotation.

Adsorption of contaminants on solid surfaces is usually expressed by empirical models, such as the Langmuir or Freundlich adsorption equations. These and other similar models relate the adsorption of a contaminant on the solid to the concentration of the contaminant in the bulk solution and to the number of adsorption sites on the solid surfaces, as a function of temperature. Most hydrophobic (water hating) organics follow these models. Therefore, removal of the contaminants can be accomplished by: a) reducing the bulk solution concentration, b) eliminating the solid surface adsorption sites, or c) changing the temperature.

Reducing the bulk solution concentration of the contaminant surrounding the solid particles can be accomplished by dilution, or by adding a mineral that has a greater affinity for the contaminant(s) than the aqueous phase. Dilution usually requires such large volumes of water that it is not practical. Therefore constituents such as surfactants or organic solvents are frequently used to reduce the bulk solution concentration.

The most difficult case to deal with is where the contaminant has chemically reacted with the solids. One approach is to try and reverse the reaction by adding suitable reagents. Another is to coat the contaminated particles with a hydrophobic coating so it can be selectively removed and concentrated, i.e. by froth flotation.

The following sections detail specifics of each technology investigated for treating the South Calvalcade site soil samples.

4.5 Soil Washing

Introduction

Soil washing is a general term used to describe various techniques utilized for removing contaminants from a solid substrate. Some example techniques are: (i) in

situ injection/recovery (ii) extraction technologies (iii) counter current decantation and (iv) froth flotation. In each of these technologies, a washing solution is applied to the contaminated soils, after the washing stage is completed the contaminated wash solution is recycled or removed and the cleaned soils are returned to the site.

Keystone utilized froth flotation in its soil washing experiments on the South calvalcade site soil samples. The separation of contaminants from soil particles depends in part to the relative wettability of the particle surfaces. Typically the surface free energy of a particle is lowered by the addition of surface active agents, i.e. surfactants. This creates a hydrophobic surface on the soil particles and, therefore, separates the soil from the contaminant particles. Most treatment systems also utilize a physical means of separating the surfactant water solution from the soil particles.

Procedure

The experiments were performed in a bench-scale Denver Equipment Company, Denver D-R flotation machine. A schematic diagram of the Denver unit used in these experiments is presented in Figure 4.5-1. The soil is introduced into the cell in the form of a water slurry and the surfactants are added with stirring. Air is introduced through the central shaft and is dispersed into the washing solution by the impeller. The contaminants are physically separated from the soil by the air bubbles and concentrated in the froth which is then scraped over the lip into another vessel.

Screening Runs

A screening run battery of soil washing tests were performed on both the surface and subsurface soil samples collected from area A-04 at the site. Conditions of the testing were altered, as well as the kinds and amounts of surfactants added, in order to optimize a soil washing procedure for the site soils tested. Table 4-5 presents the results of the three most successful screening tests performed on the eleven foot deep soil sample. Table 4-6 presents the results of the three most successful screening tests performed on the surface soil sample. In both tables the results reported have been corrected to a dry weight basis to allow direct comparisons to be made between samples. The raw untreated soil concentrations are listed so that

FIGURE 4.5 - 1
BASIC ELEMENTS
OF A DENVER UNIT

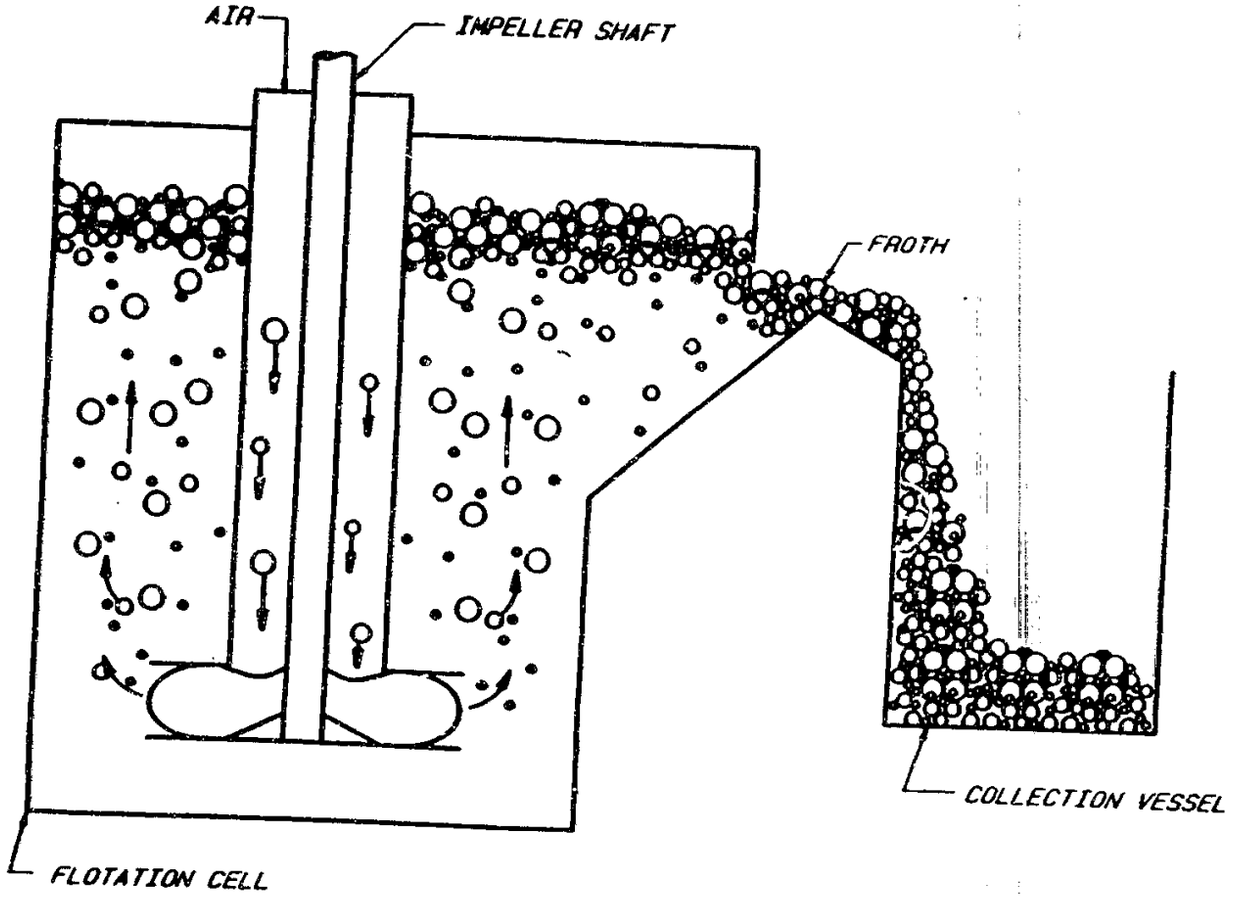

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TABLE 4-5

SOIL WASHING SCREENING RUN RESULTS
AREA A-04 SUBSURFACE SAMPLE
(RESULTS IN MG/KG, DRY WEIGHT BASIS)

Parameter (mg/kg)	Raw Untreated Soil	Test #1	Test #2	Test #5
% Solids @ 103°C	86.8	80.8	81.2	81.2
Oil and Grease	9,228 (-)	<61.9 (>99.3)	<61.6 (>99.3)	123 (98.6)
Methylene Chloride Extractables	15,092 (-)	161 (98.9)	234 (98.4)	259 (98.3)

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Test #1 Surfactants = Whitco Emcol Cocobetaine at 0.16 grams
Armak Redicote E-11 at 0.07 grams
(Total surfactants = 0.018% by weight)

Test #2 Surfactants = Rhome and Haas Triton X-100 at 0.106 grams
Whitco Emcol Cocobetaine at 0.100 grams
(Total surfactants = 0.016% by weight)

Test #5 Surfactants = Rhome and Haas Triton X-100 at 0.169 grams
Whitco Emcol Cocobetaine at 0.084 grams
(Total surfactants = 0.020% by weight)

( ) values represent % removal.
< values represent detection limit.

TABLE 4-6

SOIL WASHING SCREENING RUN RESULTS
AREA A-04 SURFACE SAMPLE
(RESULTS IN MG/KG, DRY WEIGHT BASIS)

Parameter (mg/kg)	Raw Untreated Soil	Test #1		Test #3		Test #4	
% Solids @ 103°C	86.8	81.0		81.6		82.5	
Oil and Grease	55,645 (-)	1296	(97.6)	1185	(97.8)	1300	(97.6)
Methylene Chloride Extractables	81,682 (-)	3321	(95.9)	2904	(96.4)	2752	(96.6)

007944

Test #1 Surfactants = Rhome and Haas Triton X-100 at 0.106 grams
Whitco Emcol Cocobetaine at 0.106 grams
(Total surfactants = 0.021% by weight)

Test #3 Surfactants = Olin 4750 at 0.56 grams
Armak Redicote E-11 at 0.196 grams
(Total surfactants = 0.06% by weight)

Test #4 Surfactants = Olin 4750 at 0.224 grams
Whitco Emcol Cocobetaine at 0.200 grams
(Total surfactants = 0.034% by weight)

( ) values represent % removal.
< values represent detection limit.

percent removals can be calculated. These percent removals, (from the untreated soil sample concentrations) are listed in parenthesis in the tables.

The raw data from the screening runs is presented in Appendix 10. The abbreviation T0018A represents the surface soil sample, and T0018B represents the subsurface soil sample in Appendix 10.

In all screening run tests pH adjustments were made to increase the pH, using 20% NaOH by weight. The volume of NaOH solution added varied from 0.04% to 0.4% of the total soil/water slurry volume used in each experiment. These screening run results are from one 25 minute washing cycle, followed by one 1 minute rinse cycle. The soil to water ratio used was 1:5. The surface sample test released so much creosote and oil that no foam was formed. This suggested that several washes may be necessary for the final runs in this soil washing experiment, which will also evaluate polynuclear aromatic hydrocarbon (PAH) removal.

The screening run tests achieved high percent removals of oil and grease and methylene chloride extractables as can be seen in Tables 4-5 and 4-6. All percent removals achieved were greater than 95%. The criteria used in selecting surfactant combination for use in the final runs were (1) lowest dosage (2) a common surfactant for both surface and subsurface samples and (3) pH adjustment requirements. The surfactants chosen for use in the final runs was Rhome and Haas Triton X-100 and Whitco Encol Cocobetaine. Conditions of the final runs simulated screening run test #1 for the surface soil and screening run test #5 for the subsurface soil.

Final Runs

The results of the final soil washing runs are listed in Appendix 11. The abbreviation T0018/A-RAW-F represents the raw unwashed surface soil sample, and T0018/A-C1-F represents the cleaned washed surface soil sample. Similarly T0018/B-RAW-F and T0018/B-C1-F represent the raw and cleaned washed subsurface samples, respectively. The results listed in Appendix 11 are reported as received from Keystone's laboratory i.e not corrected to a dry weight basis.

Tables 4-7 and 4-8 present the results of the final soil washing results, corrected to a dry weight basis to enable direct comparisons to be made between sample results.

TABLE 4-7(1)

FINAL SOIL WASHING RESULTS
AREA A-04 SUBSURFACE SOIL

Parameter	Raw Soil	Cleaned Soil	% Removal
% Solids @ 103°C	86.4	78.4	-
Oil and Grease (mg/Kg)	6447	68	98.9
MeCl Extractables (mg/Kg)(2)	8310	<64	>99.2
Total PAH (ug/Kg)(3)	3,747,490	23,583	99.3

007946

NOTES

Surfacants Used

First Wash:
- Rhome and Haas Triton X -100 at 0.338 grams
- Whitco Emcol Cocobetaine at 0.320 grams
- total surfactants = 0.026 wt. %
- pH maintained at 10 by adding 4 mls of 20 wt % NaOH

Second Wash:
- Rhome and Haas Triton X-100 at 0.169 grams
- Whitco Emcol Cocobetaine at 0.160 grams
- total surfactants = 0.013 wt. %
- pH maintained at 10 by adding 1.5 mls of 20 wt. % NaOH

(1) **Results reported on a dry weight basis.**
(2) **MeCl is methylene chloride solvent.**
(3) **Total PAH is total polynuclear aromatic hydrocarbons, assumed mean concentration from the statistical analysis.**

TABLE 4-8 (1)

FINAL SOIL WASHING RESULTS
AREA A-04 SURFACE SOIL

Parameter	Raw Soil	Cleaned Soil	% Removal
% Solids @ 103°C	86.6	83.0	-
Oil and Grease (mg/Kg)	57,737	1313	97.7
MeCl Extractables (mg/Kg)(2)	80,947	2181	97.3
total PAH (ug/Kg)(3)	3,747,490	836,639	77.7

NOTES

Surfacants Used

First Wash:
- Rhome and Hass Triton X-100 at 0.212 grams
- Whitco Emcol Cocobetaine at 0.320 grams
- total surfacants = 0.022 wt.%
- pH maintained at 10 by adding 4 mls of 20 wt.% NaOH.

Second Wash:
- Rhome and Haas Triton X-100 at 0.106 grams
- Whitco Emcol Cocobetaine at 0.160 grams
- total surfactants = 0.011 wt. %
- pH maintained at 10 by adding 2.5 mls of 20 wt.% NaOH

(1) Results reported on a dry weight basis.
(2) MeCl is methylene chloride solvent.
(3) Total PAH is total polynuclear aromatic hydrocarbons, assumed mean concentration from the statistical analysis.

These final runs included PAH analyses, as well as the oil and grease and methylene chloride extractable analyses. The values appearing in parenthesis are the percent removals calculated from comparison to the raw unwashed mean soil concentration obtained from the statistical analyses for the raw PAH soil concentration. The high percent removals for the oil and grease and methylene chloride extractable analyses obtained in the screening runs were duplicated in the final runs, for both soil samples tested. The PAH components had high percent removals also. The subsurface soil washing experiment obtained over 99% removal of the total PAH components present in the raw soil, and the surface soil washing experiment obtained over 77.7% removal.

Each final soil washing test employed two 45 minute wash cycles, followed by one 10 minute rinse cycle. One 45 minute wash cycle consisted of a 15 minute mixing time followed by a 30 minute washing/foaming time. The amount of surfactants added in the first wash was decreased 50% for the second washing cycle. The soil to water ratio used in all final runs was 1:5, on a weight:weight basis. Each final run utilized 500 g of site soil and 2500 mls of tap water.

The surface and subsurface soil samples used in both soil washing and soil column testing were toxicity tested by the Microtox bioassay. The surface and subsurface soils were tested before and after soil washing. The surface and subsurface soils were inadvertently sampled only before the soil column experiment. Results of the Microtox testing are reported in duplicate for the EC50 at 5 and 15 minute exposure times, in Table 4-9.

As can be seen in Table 4-9 both surface and subsurface soil samples collected from area A-04 on the site where very toxic to the luminescent bacteria used in the Microtox bioassay test. After soil washing, the Microtox toxicity decreased about 3% for the surface soils tested. This small improvement did not change the surface soils very toxic rating however. The subsurface soil samples also decreased in Microtox toxicity after soil washing, about a 13 percent decrease. The subsurface soil toxicity rating changed from very toxic to toxic after the soil washing treatment. The improvement seen was most likely due to removing the majority of oil and grease and PAH components from the soil samples treated by soil washing. However the still toxic rating after soil washing indicates that something other than the oil and grease

TABLE 4-9
MICROTOX RESULTS
SITE SOIL SAMPLES AREA A-04

Sample	EC50 5 Minutes	EC50 15 Minutes
surface soil	0.413%	0.448%
surface soil	0.445%	0.473%
soil washed surface soil	2.994%	3.420%
soil washed surface soil	3.310%	3.666%
subsurface soil	0.342%	0.379%
subsurface soil	0.353%	0.357%
soil washed subsurface soil	13.494%	14.269%
soil washed subsurface soil	12.933%	13.681%
subsurface soil used in soil columns	0.422%	0.451%
subsurface soil used in soil columns	0.432%	0.446%

007946

MICROTOX INTERPRETATION SCALE

Toxicity Rating	EC50
4 - Very Toxic	<10%
3 - Toxic	10-50%
2 - Mildly Toxic	50-75%
1 - Slightly Toxic	75-100%
0 - Non Toxic	>100%

and PAH fractions of the soil is also exerting toxicity to the luminescent bacteria used in Microtox testing.

4.6 In Situ Soil Bioreclamation

Introduction

A bench-scale soil bioreclamation experiment was performed by Keystone to evaluate the feasibility of treating South Calvalcade soils biologically on-site. This experiment attempted to simulate in situ soil conditions present at the site as closely as possible. The bioreclamation experiment involved pumping site groundwater through packed soil columns and supplying the proper nutrients and environmental conditions necessary for microbial degradation of organics present in the soil. In addition to enhancing the indigenous microorganisms present in the site soil, the soil was seeded with sludge from an aeration tank which treated tar plant wastewaters containing high concentrations of coal-tar related compounds.

For the coal tar related chemicals associated with the site, biodegradation, sorption/desorption, and volatilization are some examples of competing factors which may affect the process of in situ treatment. The degree to which each of these factors influence in situ treatment depend on such things as (i) site hydrogeologic conditions (ii) soil characteristics and (iii) physical/chemical characteristics of the contaminants of interest.

Keystone, through previous research has proven that the coal tar related chemicals can be biodegraded under the proper environmental conditions. (Keystone, 1986)[1,2,3] Further supporting the biodegradability of aromatic hydrocarbons, a paper by Gibson and Subramanian (1984)[4] showed that microbial degradation pathway studies have centered on mononuclear compounds, and with the exception of naphthalene, phenanthrene and anthracene, little is known about the exact metabolic pathways associated with the majority of polycyclic aromatic hydrocarbons. Regardless of identifying the specific metabolic pathways, it is well established that biodegradation of a majority of polycyclic aromatic hydrocarbons occurs under proper environmental conditions (Sims-1982).[5] Degradation of PAH components has been shown to be feasible by Keystone, as well as others cited in the literature both by aerobic and anaerobic microbial degradation . Overcash and Pal (1979)[6]

reference that microbes can degrade PAH's without using them as the sole source of carbon but through co-metabolism with other organics present. Referenced work examining nitrate (NO^{-3}) respiration using [^{14}C] benzoate confirmed the dissimulation of the compound to carbon dioxide thus supporting the anaerobic process with inference that such an anaerobic process is capable for biodegradation of coal tar related organics.[7,8]

Procedure

Three soil columns were packed with site soil to operate an 8 week bench-scale soil bioreclamation experiment at the Monroeville treatability laboratory. Each column was a 2' high glass cylinder, 4" in diameter, and contained 18" of 1/4 inch each screened composite subsurface soil sample, collected from area A-04 at the site. The columns were wrapped in aluminum foil to prevent the soil from being exposed to light. The ends of the columns were plugged, except for a small hole at either end for the feed, which was applied in an upflow mode through the columns. This ensured that the columns were flooded to simulate the saturated zone of soil present on site.

One column was operated as a control, one in an aerobic, and one in an anaerobic mode. To the aerobic column, hydrogen peroxide was added to supply oxygen. For the anaerobic column, sodium nitrate was added to supply nitrate, to be used as the electron acceptor in the anaerobic biodegradation process. In both the aerobic and anaerobic soil columns, a sludge seed was added to the soil at the time of loading the columns initially. This sludge seed was a biological sludge from an aeration tank treating tar plant wastewater. This sludge seed was added to enrich the soil microorganism population with microbes acclimated to using high strength organic wastewater as a food source. The feed to the anaerobic and aerobic columns was gravity settled groundwater, (a composite of Wells OW-10 and OW-11) pumped at a rate calculated to simulate the horizontal permeability of site soil. Nutrients were added to the groundwater feed in the form of ammonium phosphate dibasic $(NH_4)_2 HPO_4$, at a dosage to maintain a residual concentration of nitrogen and phosphorus in the column effluents. The control column was fed tap water only, and received no nutrients or sludge seed.

Sampling of the soil columns initially included the site soil in the control column, and the site soil plus sludge seed present in both the aerobic and anaerobic columns. The groundwater being fed was also sampled initially. Soil column effluents were collected daily in PAH cleaned containers and samples were submitted every two weeks. The effluent samples submitted for chemical analyses were taken from composite samples collected over a 1 week period, so as not to violate any sample holding times for the chemical analyses. The final sampling included the groundwater feed, and the soil in each of the three columns, at the end of the 8 week study.

Results

The influent groundwater used in the soil column experiment was a gravity settled composite sample of wells OW-10 and OW-11. This influent groundwater was sampled for the site chemicals of interest two times: at the beginning, and at the end of the 8 week long soil column study. The results from these sample analyses are presented in Appendix 12.

Bi-weekly soil column effluent samples were collected and analyzed for some site chemicals of interest used to monitor the soil column treatment process. The results of these bi-weekly effluent samples are presented in Appendix 12.

The soil used to load the soil columns was sampled twice, initially and at the end of the soil column study. The initial sampling consisted of two separate samples; one from the raw unseeded control column, and one sample from the sludge seeded subsurface soil used to load both the aerobic and anaerobic soil columns. The results of the soil analyses are presented in Appendix 12.

Influent Results

The results of the analyses performed on the groundwater used as feed for the aerobic and anaerobic soil columns, are summarized in Table 4-10. The groundwater chemical concentrations remained constant between samplings with the exception of the PAH components. The PAH concentrations decreased for all individual PAH components. The total PAH concentration decreased over 71 percent from the initial measured concentration of 4242 ug/l. The only metal out of the 13 sampled for

TABLE 4-10
SOIL COLUMN STUDY
GROUNDWATER INFLUENT RESULTS

Conventional Pollutants (mg/l)	Initial Influent Sample (1-11-88)	Final Influent Sample (3-3-88)
BOD	42.0	240
COD	240	178
Oil and Grease	20.8	26.3
Phenols (4AAP)	5.70	3.47
TKN as N	8.80	7.35
TOC	56.7	52.6
Total PO4	6.95	6.10
pH (units)	7.5	7.6
Total Detectable Metals (ug/l)		
arsenic	12.7	-
Individual PAH (ug/l)		
carbazole	304	28.1
naphthalene	2700	739
acenaphthene	352	146
acenaphthylene	178	87.8
anthracene	30.5	8.97
fluorene	189	55.9
phenanthrene	288	76.9
benzo (A) anthracene	13.1	4.60
chrysene	10.8	3.54
fluoranthene	83.5	25.3
pyrene	83.8	20.6
benzo (K) fluoranthene	1.03	0.483
benzo (A) pyrene	1.68	0.841
benzo (B) fluoranthene	2.90	1.32
dibenz (AH) anthracene	1.65	1.10
indeno (1,2,3-C,D) pyrene	0.766	0.355
benzo (G,H,I) perylene	1.62	0.630
Total PAH ug/l	4242.3	1201.4

NOTE: The groundwater was used as the influent to the aerobic and anaerobic soil columns.

that appeared above detection limit concentrations in the groundwater feed was arsenic, present in the initial sampling at 12.7 ug/l.

The flowrate of groundwater pumped through the non-control soil columns was 1.25 mls/minute, for a total volume of groundwater treated through each soil column of 26.6 gallons. The influent to the control column was tap water only, also pumped upflow at 1.25 mls/minute, for a total of 26.6 gallons for the study.

Operational Data

The soil columns were operated for eight weeks in Keystone's treatability laboratory. During the course of the study various tests were performed to monitor the influents and effluents for the soil columns to ensure proper operation. Parameters measured by test kits included phenols (4-AAP), ammonia nitrogen, ortho-phosphorus, and nitrate. Also measured regularly in the lab were dissolved oxygen concentration and pH.

007954

The control soil column received no nutrients and there were none measured in it's effluent. The pH of the control column effluent decreased for the first three weeks to remain stable at the 6.5 to 7.0 range. The dissolved oxygen of the Control soil column likewise decreased until the fourth week where it stabilized at a 0.5-1.0 mg/l range.

The anaerobic soil columns operational parameters were also kept as desired. The influent groundwater feed supplied a consistent phenol, nitrogen, and phosphorus loading to the column and the effluents collected always had some of these nutrients present. The pH of the anaerobic columns influent ranged from 7.4 to 8.0 and the effluent pH ranged from 7.3 to 7.6. The dissolved oxygen concentration maintained in the soil column was always low, and it ranged from 0.2 to 0.7 mg/l. Nitrate was added to this soil column in the form of sodium nitrate. The influent nitrate concentrations ranged from 1 to 30 mg/l and the effluent nitrate concentrations ranged from 1 to 15 mg/l. Approximately one-half of the applied nitrate to the anaerobic soil columns was consumed in the anaerobic biological reactions.

The aerobic soil column also had good operational data. The nutrients added were partly used, with a residual remaining in the column effluents. Ample dissolved

oxygen was supplied by hydrogen peroxide additions, and the dissolved oxygen concentration in the column varied from 2 to 20 mg/l. No nitrate was added or measured in the column effluent. The phenols present in the groundwater influent was all consumed after about week #3, as measured by phenols test kit of the column effluent. The pH of the aerobic column influent was approximately 7.6 and the effluent pH averaged about 6.9.

In conclusion, the operational parameters measured during the soil column study indicate that the desired environmental conditions were maintained for each soil column. The fact that nutrients added to the aerobic and anaerobic soil columns were being used is a positive indicator of biological activity. The pH decrease in the aerobic soil column is also a possible indication of some biological reduction, with subsequent production of acids. The oxygen demand exerted by the aerobic column is also another good indicator of biological activity occurring. Similarly the hydrogen peroxide usage in the anaerobic soil column indicates that some biological activity may have been occurring.

Effluent Results

The complete results of soil column effluent analyses for selected site chemicals of interest are presented in Appendix 12. These results are summarized for each soil column in Tables 4-11 through 4-13. Included in these tables is the total PAHs, which totals the 17 individual PAH components. Also included is a breakdown of the effluent PAH's by the number of benzene rings comprising the individual PAHs. The 2 and 3 ring PAH components are grouped together, as are the 4, 5 and 6 ring PAHs. This was done to illustrate the proportion of the more readily biodegradable PAH components, i.e. the lower molecular weight, more water soluble, 2 and 3 ring PAH components.

As can be seen in Table 4-11 the total PAH in the control column effluent samples remained consistent throughout the 8 week study. The large portion of the total column effluent PAHs were the more water soluble, lower ring PAHs (99 percent). The fact that the effluent PAH concentration did not decrease over the weeks of operation is an indication that no biological activity was occurring in the control column and that the effluent PAHs were merely solubilized off the soil in the columns and into the effluent.

TABLE 4-11
SOIL COLUMN EFFLUENT RESULTS
CONTROL COLUMN #1

Parameter	1-21-88	2-4-88	2-18-88	3-3-88
Phenols(4AAP) mg/l	3.54	0.439	0.206	0.137
TOC (mgl)	53.1	13.5	10.8	10.2
Total PO4 (mgl)	<0.100	-	-	-
Phosphate (o) as P (mgl)	<0.100	<0.100	<0.100	<0.100
pH	-	6.8	6.5	7.2
Total PAH (ug/l)	875.6	912.7	792.5	717.07
Naphthalene (ug/l)	742	725	670	496
2 & 3 ring PAH's	867.3(99%)	903.2(99%)	>786.9(99%)	713.54(99%)
4.5 & 6 ring PAH/s	8.36(1%)	9.54(1%)	5.6(1%)	3.53(1%)

007956

TABLE 4-12

SOIL COLUMN EFFLUENT RESULTS

ANAEROBIC COLUMN #2

Parameter	1-21-88	2-4-88	2-18-88	3-3-88
Phenols(4AAP) mg/l	2.12	1.86	1.16	1.20
TOC (mgl)	64.4	36.4	34.7	32.7
Total PO4 (mgl)	0.550	-	-	-
Phosphate (o) as P (mgl)	0.390	1.74	4.98	4.39
pH	-	7.3	7.5	7.6
Total PAH (ug/l)	181.4	164.0	145.6	66.489
Naphthalene (ug/l)	24.0	<2.00	4.3	<2.00
2 & 3 ring PAH's	167.8(92%)	146.7(89%)	128.4(88%)	55.13(83%)
4,5 & 6 ring PAH/s	13.6(8%)	17.3(11%)	17.2(12%)	11.359(17%)

007957

TABLE 4-13
SOIL COLUMN EFFLUENT RESULTS
AEROBIC COLUMN #3

Parameter	1-21-88	2-4-88	2-18-88	3-3-88
Phenols(4AAP) mg/l	2.32	2.17	0.555	0.297
TOC (mgl)	55.2	47.2	41.6	33.7
Total PO4 (mgl)	1.69	-	-	-
Phosphate (o) as P (mgl)	1.37	0.910	3.59	3.56
pH	-	6.9	7.0	7.1
Total PAH (ug/l)	363.1	658.3	185.0	181.82
Naphthalene (ug/l)	3.13	<2.00	<2.00	<2.00
2 & 3 ring PAH's	227.4(62.6%)	389.7(59.2%)	41.2(22.3%)	29.11(16%)
4,5 & 6 ring PAH/s	135.7(37.4%)	268.6(40.8%)	143.8(77.7%)	152.71(84%)

007958

Table 4-12 presents the anaerobic soil column effluent results, and as can be seen. the total PAH concentration is much less than the control columns effluent PAH concentration. Also the amount of PAH decreases as the weeks of the study progressed, indicating that biological degradation of the PAH's in the groundwater feed and/or column soil was occurring.

Also noteworthy is that the relative proportion of the more biodegradable 2 and 3 ring components is less than the control column effluent results. This would be expected if some biological degradation of PAHs was occurring. This trend also increased as the weeks of the study progressed.

Table 4-13 presents the aerobic soil column effluent results. The total PAH concentration in the effluent is also less than the control column's concentration and shows a decreasing effect over the time frame studied. The relative proportion of 2 and 3 ring PAH components is the lowest of all columns, and they decrease over time, further supporting that biological degradation was occurring. The aerobic mode of operation shows the highest reduction in the lower molecular weight PAH components of all three columns tested.

Further evidence supporting that the water phase PAH components were biodegraded can be seen by viewing the naphthalene results. The control columns results show that this water soluble PAH will be removed from site soil into the effluent phase (i.e. it was solubilized). The two seeded columns however show naphthalene removal to at, or very near, detection limit in the effluent after only one week of operation and continuing until the end of the study. This indicates that once solubilized, PAHs can be degraded biologically by the soil columns operated either aerobically or anaerobically, even in this very limited 8 week time period.

Other results from the effluent Tables 4-11 through 4-13 show that: (1) ample phosphorus was available for the biological population to utilize, (2) the phenols (4-AAP) washed out of the control column soil initially then leveled off, while the aerobic and anaerobic columns which had more phenols applied in their groundwater feeds, showed some phenol degradation, (3) TOC washed out of the control column initially then leveled off, while the aerobic and anaerobic TOC

effluent concentrations remained more consistent, and (4) the pH of all the soil columns was at or very near neutral, as desired.

Soil Results

The subsurface soil used in the soil column study was sampled twice; at the start and at the end of the 8 week study. The results of the soil sample analyses are presented in Appendix 12, as received from Keystone's Monroeville laboratory. The initial sampling results are labeled seeded col. and raw col. which stand for the sludge seeded subsurface soil, and the subsurface soil respectively. The aerobic and anaerobic soil columns included a sludge seed along with the subsurface soil, while the control column was loaded with subsurface soil sample only. The final soil sampling results are labeled by the mode of operation, i.e. aero. for the aerobic, anaer. for the anaerobic, and control for the control column.

The results given in Appendix 12 are summarized in Tables 4-14 through 4-16 for each column on a dry weight basis, to allow direct comparison to be made between different sample results. The soil results obtained were inconclusive, with very wide variations of chemical concentrations measured between samplings. Due to the uncertainty of the soil sample results, no statistically valid conclusions can be made concerning the soil column performance with regard to the soil phase.

4.7 Slurry Reactors

As part of the biodegradation work performed using site groundwater and soil samples, Keystone also performed testing using two "slurry reactors." These slurry reactors, also called suspended growth biological reactors, each contained subsurface soil from area A-04 and enough gravity settled groundwater to form a 2500 ml slurry. The amount of groundwater and soil needed to form this 2500 ml working volume of slurry was 1953 grams of soil and 1563 mls of groundwater. This laboratory testing did not attempt to simulate any site hydrogeologic conditions, but instead was designed to provide the environmental conditions necessary to maintain an in situ microbial population capable of degrading the chemicals of interest, i.e. PAH's. The major differences between this work and the soil column study was that this shorter duration (1 month) slurry testing by design was not as mass transfer limited as were the columns. The constant mixing provided maximum soil/water contact in the

TABLE 4-14
SOIL COLUMN SOIL RESULTS
CONTROL COLUMN #1

Parameter	Initial (1-11-88)	Final (3-3-88)
TOC mg/kg	23,121	13,977
Oil & Grease (mg/kg)	5,584	11,220
Phenol (mg/kg)	35.6	1.80
Phosphorous (mg/kg)	<11.5	<63.5
PH (units)	8.39	7.69
TKN (mg/kg)	147.9	278
% Solids @ 103°C	86.5	78.7
MeCl extractables (mg/kg)	12,023	3,761
Total PAH (ug/kg)	3,348,941	140,966
Total Metals (ug/kg)		
• Antimony	<6000	<6000
• Arsenic	9,480	50,953
• Beryllium	<500	1,360
• Cadmium	<500	<500
• Chromium	77,600	19,314
• Copper	2,530	9,199
• Lead	6,450	7,865
• Mercury	<100	1,741
• Nickel	<4000	<4000
• Selenium	<500	<500
• Silver	<1000	<1000
Cationic Exchange Capacity (ug/kg)		
• Sodium	71.5	
• Thallium	<1000	<1000
• Zinc	144,000	47,903
EPTOX Metals (mg/l)		
• Arsenic	<0.500	<0.500
• Barium	<0.200	<0.200
• Cadmium	<0.005	<0.005
• Chromium	<0.010	<0.010
• Copper	<0.025	<0.025
• Lead	<0.100	<0.100
• Mercury	<0.0002	<0.0002
• Selenium	<0.500	<0.500
• Silver	<0.010	<0.010
TCLP Metal (mg/l)		
• Arsenic	<0.500	<0.500
• Chromium	<0.010	<0.010
• Copper	<0.025	<0.025

NOTE: All reported results are on a dry weight basis.

TABLE 4-15
SOIL COLUMN SOIL RESULTS
ANAEROBIC COLUMN #2

Parameter	Initial (1-11-88)	Final (3-3-88)
TOC mg/kg	19,640	14,599
Oil & Grease (mg/kg)	85.6	10,839
Phenol (mg/kg)	40.4	3.77
Phosphorous (mg/kg)	<12.8	99.5
PH (units)	7.96	8.19
TKN (mg/kg)	252.9	291
% Solids @ 103°C	77.9	77.4
MeCl extractables (mg/kg)	359.4	2532
Total PAH (ug/kg)	942,849	2,027,519
Total Metals (ug/kg)		
- Antimony	<6000	<6000
- Arsenic	38,400	19,767
- Beryllium	<500	1,382
- Cadmium	<500	<500
- Chromium	22,400	123,773
- Copper	<2,500	7933
- Lead	4820	7584
- Mercury	<100	3049
- Nickel	<4000	<4000
- Selenium	<500	<500
- Silver	<1000	<1000
Cationic Exchange Capacity (ug/kg)		
- Sodium	81.0	
- Thallium	<1284	<1000
- Zinc	94,736	157,623
EPTOX Metals (mg/l)		
- Arsenic	<0.500	<0.500
- Barium	<0.200	<0.200
- Cadmium	<0.005	<0.005
- Chromium	<0.010	<0.010
- Copper	<0.025	<0.025
- Lead	<0.100	<0.100
- Mercury	<0.0002	<0.0002
- Selenium	<0.500	<0.500
- Silver	<0.010	<0.010
TCLP Metal (mg/l)		
- Arsenic	<0.500	<0.500
- Chromium	<0.010	<0.010
- Copper	<0.025	<0.025

NOTE: All reported results are on a dry weight basis.

TABLE 4-16
SOIL COLUMN SOIL RESULTS
AEROBIC COLUMN #3

Parameter	Initial (1-11-88)	Final (3-3-88)
TOC mg/kg	19,640	8,723
Oil & Grease (mg/kg)	85.6	9,153
Phenol (mg/kg)	40.4	3.29
Phosphorous (mg/kg)	<12.8	78.4
PH (units)	7.96	7.34
TKN (mg/kg)	252.9	250
% Solids @ 103°C	77.9	79.1
MeCl extractables (mg/kg)	359.4	1094
Total PAH (ug/kg)	942,849	4,070,544
Total Metals (ug/kg)		
- Antimony	<6000	<6000
- Arsenic	38,400	9027
- Beryllium	<500	1302
- Cadmium	<500	<500
- Chromium	22,400	11,530
- Copper	<2,500	4,513
- Lead	4820	5,474
- Mercury	<100	2,491
- Nickel	<4000	<4000
- Selenium	<500	<500
- Silver	<1000	<1000
Cationic Exchange Capacity (ug/kg)		
- Sodium	81.0	-
- Thallium	<1000	<1000
- Zinc	94,736	34,260
EPTOX Metals (mg/l)		
- Arsenic	<0.500	<0.500
- Barium	<0.200	<0.200
- Cadmium	<0.005	<0.005
- Chromium	<0.010	<0.010
- Copper	<0.025	<0.025
- Lead	<0.100	<0.100
- Mercury	<0.0002	<0.0002
- Selenium	<0.500	<0.500
- Silver	<0.010	<0.010
TCLP Metal (mg/l)		
- Arsenic	<0.500	<0.500
- Chromium	<0.010	<0.010
- Copper	<0.025	<0.025

NOTE: All reported results are on a dry weight basis.

reactors. Hence these slurry reactors served as accelerated biodegradation units, giving a quick prediction as to the feasibility of using biological degradation at this site. Due to time constraints imposed on the study, this slurry reactor work was performed concurrently with the soil column experiment, rather than before it.

Procedure

Presented in Figure 4.7-1 are schematic diagrams of the aerobic and anaerobic bench-scale reactors used in this study. Each reactor contained 2500 mls of slurry in the total 4000 ml volume capacity of the glass reactors. An electric stirrer was mounted inside each reactor and it turned just fast enough to keep the soil in suspension. The aerobic reactor was supplied humidified air through porous airstones in order to maintain a minimum dissolved oxygen concentration of 3 mg/l throughout the study. The anaerobic reactor was supplied with a nitrogen gas blanket on top of the slurry surface to maintain anaerobic conditions in the reactor. Tap water was used to make up for daily evaporation losses. Water removed for testing was not replaced,so as not to dilute the slurry mixture.

The pH of both slurry reactors was monitored daily and they remained about neutral, at 7. Nutrients were added to each reactor by the addition of ammonium phosphate dibasic, so that a residual concentration of both nitrogen and phosphorus was maintained in the slurries. For the anaerobic reactor sodium nitrate was added as a nitrate source for use in the anaerobic treatment process.

Test kit analyses were performed three times per week, measuring nitrogen, phosphorus, and nitrate concentrations present in the slurry. The reactors were run for a total of four weeks. The soil and groundwater used initially to seed the reactors was sampled, as was the soil phase and water phase of each reactor after the end of week #4.

Results

At the conclusion of this experiment the soil was separated from the water phase by filtration. The water phase was light brown in color and contained fine particles in suspension (assumed to be clay), which made filtering difficult. The final pH of the aerobic water phase was 7.4 and the anaerobic was 7.3. The pH fluctuated from 6.6

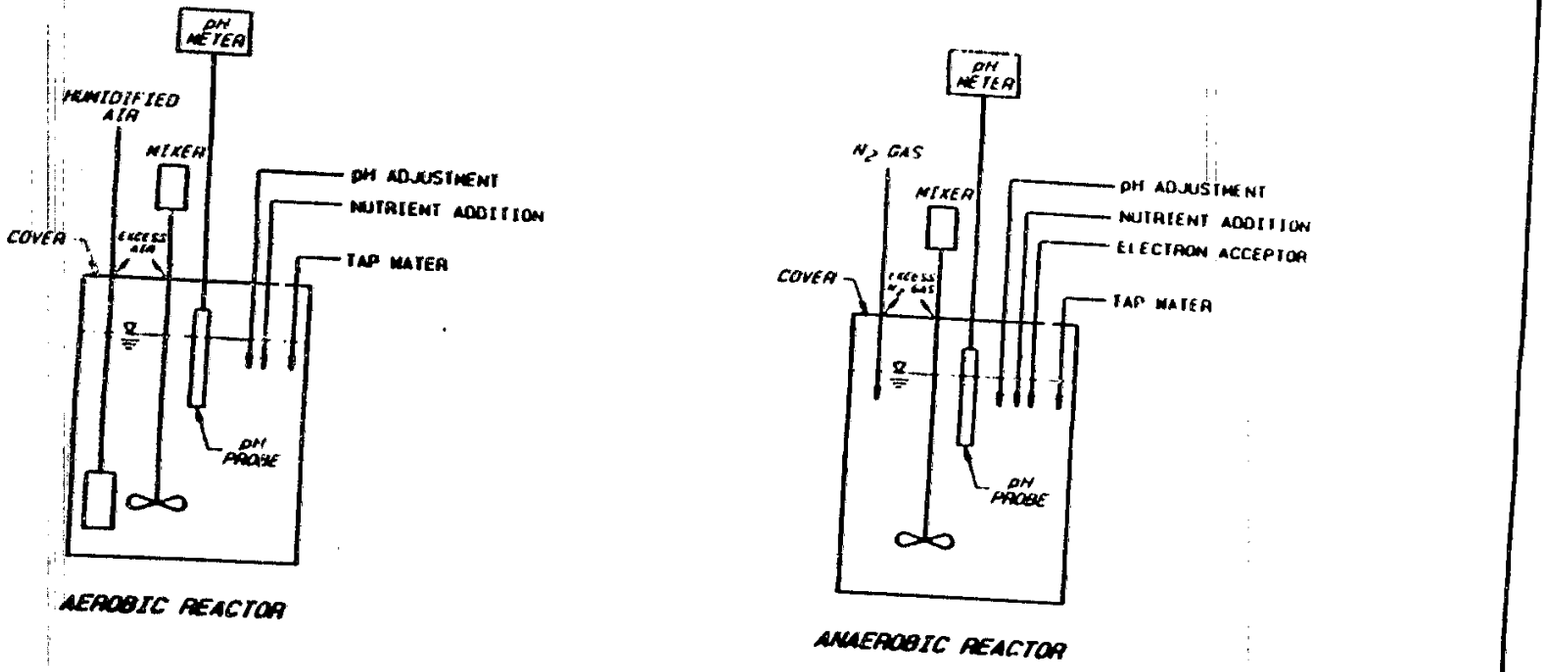

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FIGURE 4.7 - 1

SCHEMATIC DIAGRAM OF THE SUSPENDED GROWTH BIOLOGICAL REACTORS

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to 7.4 throughout the study. The dissolved oxygen concentration in the aerobic reactor ranged form 4 to 8 with an average value of 6.4 mg/l, and the anaerobic slurry reactor's dissolved oxygen varied from 0.15 to 1.0 mg/l, with an average value of 0.36 mg/l.

The aerobic reactor experienced several violent foaming incidences as laboratory house air was added to maintain the dissolved oxygen concentration. An estimated 725 mls of water, and a minimal amount of soil were lost as the foam spilled out of its reactor several times at night. Tap water was added to make-up the reactor volume, therefore, the aerobic water phase was diluted approximately 1/3 due to this unexpected foaming problem. After the initial foaming incident a commercial antifoam product (DOW P-2000) was added. The foaming subsided but returned a week later. Air addition to the aerobic reactor was kept at a minimum, to achieve a dissolved oxygen concentration of 3.0 mg/l in the reactor, to help alleviate this foaming problem.

The nitrogen concentrations were measured by test kit analyses in the lab. The aerobic reactor used an average of 1.2 mg/l of nitrogen per day, and the anaerobic reactor used an average of 0.85 mg/l of nitrogen per day. Phosphorus was similarly monitored throughout the study. The average daily use of phosphorus was: aerobic 1.5 mg/l, and the anaerobic 1.2 mg/l. Additionally the anaerobic slurry reactor was supplied nitrate by adding sodium nitrate ($NaNO_3$). The nitrate served as an electron acceptor in the anaerobic degradation reactions, similar to the role oxygen played in the aerobic reactor. The average nitrate concentration used per day by the anaerobic slurry reactor was approximately 3 mg/l. These test kit measurements for nutrients and nitrate showed very consistent daily amounts used by the slurry reactors. This can be viewed as a positive indication of biological activity occurring in the reactors.

The chemical analyses of the slurry reactor's water and soil phases are presented in Appendix 13. The first section presents the initial concentrations and the second section presents the final concentrations after 4 weeks of operation. The results listed in Appendix 13 are as received from Keystone's Monroeville laboratory, i.e. soil results are not corrected to a dry weight basis.

Table 4-17 lists the results of the slurry reactor testing with the soil results corrected to a dry weight basis to allow direct comparison between samples. The listed initial soil concentration is the assumed soil PAH concentration obtained from the statistical analysis of the six data sets of raw untreated soil PAH concentration measurements. Initial water and soil concentrations are listed as well as the final soil and water concentrations after four weeks of operation. The percent removals from initial soil and water concentrations are calculated and listed for both the aerobic and anaerobic slurry reactors.

The aerobic reactor showed a 61.6 percent decrease in total PAH concentration in the water phase. The biological population in the slurry degraded the soluble PAH's after they left the surfaces of the soil particles and went into the liquid phase. The anaerobic reactor also showed a decrease in the water phase PAH components with over 88 percent reduction in total PAHs obtained. The daily use of nutrients, nitrogen, phosphorus, and nitrate for the anaerobic reactor support that the decrease in PAH concentration in the water phase was due to biological degradation, both aerobically and anaerobically. Additionally supporting this phenomena is the results of individual PAH components. The lower 2 and 3 ring molecular weight PAH's are those which are more water soluble and are more readily biodegraded than are the less soluble higher 4, 5 and 6 ring compounds. For example, the naphthalene (a 2 ring PAH) concentration in the initial slurry reactor water phase was 1910 ug/l, and in the final water phase of the aerobic reactor it was 12.3 ug/l. This represents a 99% decrease in concentration. Similarly carbazole (a 2 ring PAH) showed a 97% decrease, and acenaphthylene (a 3 ring PAH) showed a 51% decrease, in the aerobic slurry reactor. The anaerobic slurry reactor water phase showed similar high removal rates for the low ring PAH components: naphthalene >99%, and carbazole >97%, (acenaphthylene had an interference in final testing and no result was reported).

The soil phase of the slurry reactor experiment presents the same problem addressed earlier concerning the wide variations encountered in analyzing a heterogeneous soil matrix by a very sensitive analytical technique. This becomes even more of problem when the PAH concentrations are elevated. For this reason, it is difficult to interpret the soil results from one PAH measurement from each treated slurry reactor soil. The high PAH concentration found in the one treated anaerobic soil test was the highest of all measurements in the treatability work, at twice the next highest soil

TABLE 4-17
SLURRY REACTOR RESULTS[1]

AEROBIC SLURRY REACTOR

Parameter	Initial Water	Final Water	Percent Removal	Initial Soil	Final Soil	Percent Removal
pH	7.4	7.4	-	8.53	7.22	15.4
% Solids	-	-	-	86.7	74.1	14.5
Total PAH (ppb)[2]	2311.4	888.0	61.6	3,747,490[3]	1,999,825	46.6

ANAEROBIC SLURRY REACTOR

Parameter	Initial Water	Final Water	Percent Removal	Initial Soil	Final Soil	Percent Removal
pH	7.4	7.3	1.4	8.53	7.33	14.1
% Solids	-	-	-	86.7	77.6	10.5
Total PAH (ppb)[2]	2311.4	275.2	88.1	3,747,490[3]	5,046,289	(+)

(1) The results reported are on a dry weight basis.
(2) Total PAH (ppb) = Total polynuclear aromatic hydrocarbons, in parts per billion (ug/l for the water phase, and ug/kg for the soil phase).
(3) Total PAH mean value from statistical analysis, assumed raw soil concentration.
(4) (+) indicates an increase in that parameter's concentration.

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PAH result obtained in the study. It would be unwise to attempt to draw any conclusions from one soil result for each slurry reactor soil due to the inherent variations of analytical results discovered during these soil analyses.

4.8 Activated Sludge Co-Treatability

Introduction

As part of the initial technology screening selection process, activated sludge treatment for the groundwater was proposed for inclusion in the laboratory evaluation. Based upon both published literature, and Keystone's in-house data on biological treatment of wood treating wastewaters, it was decided not to spend any of the treatability budget on evaluating a technology which is proven to be technically feasible on the chemicals of interest found at the South calvalcade site. Additionally the concept of co-treatability would be difficult to accurately simulate on a bench-scale and is better suited for a pilot plant study. A 1987 Keystone pilot plant study which tested the concept of co-treatability, proved it to be technically feasible, and will be used as an example for comparison to the South Calvalcade site.

The pilot plant treatability study was designed to treat groundwaters form Former Manufactured Gas Plant (MGP) sites in conjunction with municipal wastewaters, at a Publicly Owned Treatment Works (POTW). Specifically this study was performed at a New York POTW which uses conventional activated sludge treatment and has an average daily flow of about 1 million gallons per day (1 MGD). This pilot study was designed as a research project for the government, as well as a specific MGP site remediation project for a utility company client. The chemicals of interest for the MGP sites listed in Table 4-18 include all of the chemicals of interest found at the South Calvalcade site.

The majority of the chemicals of interest are biodegradable to different degrees in an activated sludge process, with some exceptions, i.e. metals. However, the fate of these chemicals once added as feed to a POTW activated sludge wastewater treatment process is not presently known. For this reason, the investigative pilot work was performed.

TABLE 4-18

"CHEMICALS OF INTEREST" ASSOCIATED WITH MGP SITES

• INORGANICS	• METALS	• VOLATILE AROMATICS	• PHENOLICS	• POLYNUCLEAR AROMATIC HYDROCARBONS
AMMONIA	ALUMINUM	BENZENE	PHENOL	ACENAPHTHENE
CYANIDE	ANTIMONY	ETHYL BENZENE	2-METHYLPHENOL	ACENAPHTHYLENE
NITRATE	ARSENIC	TOLUENE	4-METHYLPHENOL	ANTHRACENE
SULFATE	BARIUM	TOTAL XYLENES	2, 4-DYMETHYL-PHENOL	BENZO (A) ANTHRACENE
SULFIDE	CADMIUM			BENZO (A) PYRENE
THIOCYANATES	CHROMIUM			BENZO (B) FLUORANTHENE
	COPPER			BENZO (G, H, I) PERYLENE
	IRON			BENZO (K) FLUORANTHENE
	LEAD			CHRYSENE
	MANGANESE			DIBENZO (A, H) ANTHRACENE
	MERCURY			DIBENZOFURAN
	NICKEL			FLUORANTHENE
	SELENIUM			FLUORENE
	SILVER			NAPHTHALENE
	VANADIUM			PHENANTHRENE
	ZINC			PYRENE
				2-METHYLNAPHTHALENE

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Reference: Management of Manufactured Gas Plant Sites, Volume IV Site Restoration, Keystone Environmental Resources et al, GRI-87/0260.4

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Procedure

The pilot plant simulated the operating conditions present at the POTW, in order to evaluate the effects of adding industrial type groundwater feeds into an acclimated population of microorganisms treating raw sewage. The pilot plant consisted of three separate reactors each consisting of a 45 gallon activated sludge aeration tank and a 30 gallon external clarifier, all made out of stainless steel. One reactor served as a control unit, and received only POTW influent. The second reactor was fed a mixture of 20% industrial groundwater and 80% POTW influent. The industrial site groundwater was collected from a former coke plant site which contained elevated concentrations of coke and coal tar components. The level of contamination present in the industrial site groundwater was much higher than the MGP site groundwater, or the South Calvalcade site groundwater. As such, this industrial site feedwater served as a worse case treatment scenario for the activated sludge experiment. The elevated concentrations present in the industrial site groundwater, ensured that dilution alone would not render the influent concentrations to the biological reactor below detectable limits. The third reactor was fed 5% MGP site groundwater and 95% POTW influent water. The 5% figure for the MGP site was based upon the estimated dilution of site groundwater if all of it was pumped to the POTW for treatment. This ratio was actually less than 1% but was increased to provide a safety factor and to allow possible future higher pumping rates from the site. Even at this higher percentage, influent chemical concentrations for the MGP site reactor were below detectable limits, due to the dilution effect alone.

All three reactors were maintained at a solids retention time (SRT) of approximately 13.5 days, and the hydraulic retention times (HRT) were maintained approximately 8 hours. The reactors were operated for a total of 50 days with steady-state conditions assumed during the last 10 days of operation. At this assumed time for beginning steady-state operation, the initial seed activated sludge was 87% "washed-out" from the reactors. Thus the sludges in each of the three reactors were representative of the long term sludges which would be obtained from treating each of the respective influent wastewaters.

During operation of the pilot plant intensive sampling and analyses were performed on each reactor, which included: the influent and effluent streams, the raw waters used to make the influent, the wasted biological sludge from the aeration tank, a

microbial identification/quantification of the mixed liquor biological sludge population, bioassay work on the influent and effluent streams, and air emissions from the aeration tank.

Issues of concern for this study were many, some examples include: (1) the effects of adding metals and PAH compounds into the feed where previously none had existed, and how this would affect the effluent quality, the microbial population, and the resultant wasted sludge (2) the speed of acclimation to the new industrial feed sources, as well as how this new feed would affect unit operations, i.e. sludge settling characteristics, aeration requirements, F/M ratios (food to microorganism ratios), sludge recycle ratios, hydraulic retention times (HRT), sludge retention times (SRT), and other sanitary engineering type concerns.

Summary of Results

Results and interpretation of the investigative work performed is summarized in the following paragraphs.

The control reactor influent municipal wastewater contained no detectable levels of the chemicals of interest. As designed, the MGP reactor had no chemicals of interest in the influent above detection limit. This was the case due to dilution of the influent, even though the raw water collected form the MGP site did contain most of the chemicals of interest at elevated concentrations. The industrial (site) reactor contained the chemicals of interest above detectable limits in the influent, even after a 1:4 part dilution of groundwater to POTW influent water. Table 4-19 lists the mean influent concentrations to each of the three reactors during the pilot study.

In terms of operational parameters i.e. dissolved oxygen concentration, pH, bacterial solids concentration, HRT, SRT, sludge recycle ratios, etc., there were no significant differences among the three reactors. As cited in Table 4-20 all three reactors produced the same treated clarified effluent quality in terms of: conventional, inorganic, volatile aromatics, and metals chemical parameters. In terms of total phenolics and total PAH, the industrial site reactor showed slightly higher effluent concentrations. Even though some of the chemicals of interest were detected in the industrial site reactors effluent, the concentrations measured were below Best

TABLE 4-19

INFLUENT WATER QUALITY RESULTS
STEADY-STATE MEAN CONCENTRATIONS(1)
($\bar{x}$ ± 95% CI)

Chemical Parameter	Control Unit	(MGP) Reactor A	(Industrial) Reactor B
Conventional:			
pH (units)	7.3 ± 0.1	7.2 ± 0.1	7.2 ± 0.1
TSS	82 ± 49	74 ± 27	121 ± 83
VSS	77 ± 54	57 ± 10	105 ± 72
FSS	6 ± 5	18 ± 25	22 ± 22
TOC	41 ± 14	39 ± 9	49 ± 15
BOD-T	52 ± 36	46 ± 28	54 ± 30
BOD-S	32 ± 13	27 ± 9	32 ± 21
COD-T	181 ± 83	142 ± 34	171 ± 64
COD-S	93 ± 36	82 ± 41	119 ± 79
O & G	26 ± 12	24 ± 24	23 ± 5
TDS	748 ± 170	718 ± 92	645 ± 77
TDVS	152 ± 145	89 ± 28	84 ± 31
TDFS	596 ± 50	629 ± 72	561 ± 50
Conductivity (umhos/cm)	844 ± 94	872 ± 51	819 ± 59
Alkalinity as $CaCO_3$ (pH 4.5)	306 ± 39	280 ± 25	293 ± 18
TKN	18 ± 1	19 ± 3	19 ± 3
Ortho-Phosphate	1.6 ± 0.1	0.9 ± 2	1.2 ± 1.2
Inorganics:			
Ammonia Nitrogen	15 ± 3	15 ± 3	15 ± 2
Nitrate Nitrogen	0.06 ± 0.07	0.06 ± 0.1	0.07 ± 0.1
Sulfate	70 ± 7	90 ± 24	62 ± 12
Sulfide	1.46 ± 0.83	<1 ± 0	<1.1 ± 0.3
Thiocyanate	<1.2 ± 0.5	<1 ± 0	<1 ± 0
Total Cyanide	<0.01 ± 0	0.03 ± 0.01	0.03 ± 0.01
Volatile Organics:			
Benzene (ug/l)	<2.37 ± 0.63	<2.47 ± 0.81	346 ± 195
Toluene (ug/l)	6.67 ± 7.92	8.86 ± 5.94	163 ± 132
Total Xylenes (ug/l)	<4.4 ± 3.9	5.34 ± 5.16	171 ± 123
Phenolics:			
Total Phenolics (ug/l)	331 ± 178	269 ± 170	937 ± 474

TABLE 4-19 (continued)

INFLUENT WATER QUALITY RESULTS
STEADY-STATE MEAN CONCENTRATIONS(1)
($\bar{x}$ ± 95% CI)

Chemical Parameter	Control Unit	(MGP) Reactor A	(Industrial) Reactor B
Polynuclear Aromatic Hydrocarbons:			
Total PAH (ug/l)	<23.9 ± 38.7	<9.96 ± 0	3607.1 ± 3654.4

NOTE: (1)All values in mg/l unless otherwise noted.

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TABLE 4-20

CLARIFIED EFFLUENT WATER QUALITY RESULTS STEADY-STATE MEAN CONCENTRATIONS ($\bar{X} \pm$ 95% CI)

WATER QUALITY PARAMETER	CONTROL REACTOR	(MGP) REACTOR A	(INDUSTRIAL) REACTOR B
CONVENTIONAL:			
pH, UNITS	7.8 ± 0.17	7.9 ± 0.2	7.9 ± 0.2
Alk. as $CaCO_3$ (pH-4.5)	213 ± 16	189 ± 15	202 ± 21
TOTAL SUSPENDED SOLIDS	16 ± 4	12 ± 3	19 ± 3
TKN	1.92 ± 2	1.2 ± 0.5	1.52 ± 1.1
ORTHO-PHOSPHATE	1.99 ± 0.4	0.6 ± 0.1	0.7 ± 0.6
TOTAL ORGANIC CARBON	10 ± 2	6.5 ± 1.5	8.6 ± 1
BOD_5 -T	9 ± 5	6 ± 2	7 ± 1.5
BOD_5 -S	2 ± 1	2 ± 1	1 ± 1
COD -T	32 ± 11	26 ± 9	36 ± 9
COD -S	27 ± 5	15 ± 11	27 ± 6
OIL AND GREASE	<6 ± 0	<6 ± 1	<6 ± 0
INORGANIC:			
AMMONIA NITROGEN	<1 ± 0	<1 ± 0	<1 ± 0
TOTAL CYANIDE	<0.01 ± 0	<0.01 ± 0	<0.01 ± 0
NITRATE	14 ± 1	13 ± 1	12 ± 2
SULFIDE	<1 ± 0	<1 ± 0	<1 ± 0
THIOCYANATE	<1 ± 0	<1 ± 0	<1 ± 0
SULFATE	73 ± 3	100 ± 3	64 ± 5
VOLATILE AROMATICS:			
BENZENE, µg/l	<0.98 ± 1.16	<0.91 ± 1.24	<1.03 ± 1.1
TOLUENE, µgl	<0.92 ± 1.22	<0.56 ± 1	<0.92 ± 1.2
XYLENE, µgl	<1.4 ± 1.84	<0.84 ± 1.5	<1.38 ± 1.8
TOTAL PHENOLICS:, µg/l	18.9 ± 15.02	16 ± 9	32 ± 27
TOTAL PAH:, µg/l	<9.96 ± 0	<9.96 ± 0	19.22 ± 5

NOTE: ALL VALUES EXPRESSED IN mg/l UNLESS OTHERWISE NOTED.
< VALUES INDICATE LESS THAN DETECTABLE CONCENTRATIONS.

...BAT) treated discharge standards recently set for the organic ... (Federal Register 42522, November 5, 1987).

...air monitoring results, the industrial site reactor was the only ... which had measurable aeration tank volatilization of benzene, ...alene, and naphthalene.

...lculation on the wasted sludge presented in Table 4-21 indicates ... reactor's sludge contained greater amounts of volatile aromatics, ...d total PAH components than the control or the MGP reactors.

...ntration of the wasted activated sludge for all three units was ...ely the same. Table 4-22 presents analyses performed on the wasted ...sludge from each unit for some of the key chemicals of interest.

...ay ... performed in this study used the Microtox™ bioassay, acute ... method. All three clarified effluents showed no Microtox toxicity, even ...ndustrial reactor's influent was acutely toxic, based on Microtox testing.

... the results of this study support that the addition of MGP site ... into municipal wastewater streams should result in non-measurable ... terms of activated sludge treatment performance, and non-significant ... terms of treated discharge quality.

...ystone Data Base

...ystone has performed many biological wastewater treatment projects on wood ..., coke plant, coal tar, and other related chemicals of interest similar to those ...und at the South Calvalcade site. Generally high percent removals were obtained ... all cases by using the activated sludge treatment technology. For illustrative ... purposes all extract from a report which Keystone prepared for the MGP site work is ...given, which lists 19 cases of successful application of biological treatment using the ...activated sludge process. Keystone also has other successful examples of activated ...sludge treatment on bench, pilot, and full scales, as well as other methods of ...biological treatment, for chemicals of interest similar to those found at the South Calvalcade site. Generally the wastewaters treated by Keystone contain chemicals of

TABLE 4-21

(INDUSTRIAL)

REACTOR B MASS BALANCE RESULTS

PAH COMPONENT	# OF RINGS	SOLUBILITY µg/L	% OF INFLUENT VOLATILIZED	% OF INFLUENT IN WASTE SLUDGE	% OF INFLUENT BIODEGRADED	% OF INFLUENT IN CLARIFIED EFFLUENT
NAPHTHALENE	2	31700	4.2	0	95.8	0
ACENAPHTHENE	3	3930	-	0	100	0
ACENAPHTHYLENE	3	-	6.8	0	93.2	0
ANTHRACENE	3	73	<2.5	0	100	0
FLUORENE	3	1980	<0.3	0	100	0
PHENANTHRENE	3	1290	<0.4	0	100	0
BENZO (A) ANTHRACENE	4	14	<0.2	3.0	93.4	3.6
CHRYSENE	4	2	<1.9	3.2	91.4	5.4
FLUORANTHENE	4	260	<0.3	0.4	99.6	0
PYRENE	4	135	<0.3	1.6	98.1	0.3
BENZO (K) FLUORANTHENE	5	-	<1.3	25.5	53.2	21.3
BENZO (A) PYRENE	5	3.8	<0.6	21.5	59	19.5
BENZO (B) FLUORANTHENE	5	-	<0.5	30	48	22
DIBENZ (A, H) ANTHRACENE	5	2.49	<1.4	30.1	45.5	24.4
INDENO (1, 2, 3-C, D) PYRENE	6	-	<1.9	29.9	51	19.1
BENZO (G, H, I) PERYLENE	6	0.26	<1.2	31.2	45.8	23

NOTE: LESS THAN VALUES "<" ARE CONSIDERED AS ZERO VALUES.

TABLE 4-22

WASTE ACTIVATED SLUDGE QUALITY RESULTS
STEADY-STATE MEAN CONCENTRATIONS
($\bar{X}$ ± 95%CI)

CHEMICAL PARAMETER	CONTROL UNIT (MCP)	REACTOR A (INDUSTRIAL)	REACTOR B
CONVENTIONAL			
• pH, UNITS	7.4 ± 0.9	7.5 ± 0.2	7.6 ± 0.2
• OIL & GREASE	4,156 ± 7,464	3,245 ± 1,901	5,189 ± 4,660
• TOTAL PHOSPHORUS	11,078 ± 890	24,653 ± 4,468	24,121 ± 5,234
• TKN	66,382 ± 109,500	61,516 ± 90,149	67,820 ± 71,306
• BTU/LB	311	–	–
VOLATILE AROMATICS			
• BENZENE	<0.308 ± 0.111	<0.351 ± 0.247	6.848 ± 20.759
• TOLUENE	<0.350 ± 0.361	<0.248 ± 0.118	0.665 ± 1.150
• XYLENE	<0.213 ± 0.544	<0.271 ± 0.355	<0.667 ± 0.935
TOTAL PHENOLICS	324 ± 554	167 ± 221	774 ± 1,228
TOTAL PAH	7 ± 4.6	6 ± 3	449 ± 514

NOTE: ALL RESULTS IN mg/kg (DRY WEIGHT) UNLESS OTHERWISE INDICATED.
< VALUES INDICATE LESS THAN DETECTABLE CONCENTRATIONS

interest present in higher concentrations than those measured in the South Calvalcade site groundwater. Of concern for the South Calvalcade site is that the groundwater may not contain enough soluble biodegradable organics to maintain the organic loading rate needed to support the large population of organisms present in an activated sludge system by feeding groundwater alone. Hence the concept of co-treatability was considered to be a technically feasible solution for treating site groundwater by using the activated sludge process.

Relevant performance data was obtained from Keystone's in-house data base for tar plant, coke plant, chemical plant, and wood preserving (creosote) plant wastewaters. Nineteen separate cases were noted using different wastewaters and/or operating conditions. All of the data were obtained from bench-scale or pilot-scale wastewater treatability studies except for one full-scale study (Case 11). These wastewaters contained compounds which are similar to MGP site components including: phenolics, polynuclear aromatic hydrocarbons (PAHs), benzene, toluene, xylene (BTX), some metals, and various indicator parameters, i.e. oil and grease, ammonia.

The performance data from the nineteen cases (1-19) are presented in Appendix A of this report. Included in Appendix A are the range of operating conditions followed by the specific performance data in the form of percent removals based upon influent and effluent analytical values. The following is a summary of the performance data broken down by the type of chemical compound analyzed.

- o Phenols (4-AAP) removal was very good with removal rates generally exceeding 99 percent. The influent phenols concentration ranged from 21 mg/l to 1,041 mg/l and effluent phenols concentrations were 0.005 mg/l to 1.81 mg/l.

- o Total cyanide, ammonia nitrogen, and thiocyanates (SCN) were also removed quite well from the wastewater in two particular cases (5,6). These two cases focused on the removal of these parameters through biological nitrification. Ammonia nitrogen, thiocyanate, and cyanide were removed by greater than 99 percent in both cases except for cyanide (98.8 percent) and ammonia (95 percent) in case 6. Influent ammonia nitrogen ranged from 1,131 mg/l to 33.9 mg/l and effluent values from 4.05 mg/l to 1.51 mg/l. Influent thiocyanate values were

430 mg/l and 570 mg/l with corresponding effluent values of 1 mg/l and 1.39 mg/l. Total cyanide values were 207 mg/l influent with 0.86 mg/l effluent, and 242 mg/l influent with 2.96 mg/l effluent.

- Three cases (5, 11, 19) show pertinent data relative to three purgeable aromatics: benzene, toluene, xylene (BTX). In all cases these compounds were removed by greater than 99 percent. Influent benzene ranged from 0.0765 mg/l to 5.35 mg/l and was reduced to less than 0.01 mg/l to 0.008 mg/l (effluent). Influent xylene (9.9 mg/l to 11.4 mg/l) was reduced to 0.057 mg/l to 0.012 mg/l (effluent). It was not quantified as to what portion of the removal, if any, was due to air stripping and what was due to biologically degradation.

- Results of the PAH performance data were also good. In most cases, PAH were removed by greater than 95 percent.

- There was little data found on metals removal using the activated sludge process. The activated sludge process is not a process through which metals are deliberately removed, however, some removal may take place by which the metals are attached to the biological solids and are settled with the sludge. For this reason, the metals concentration in activated waste sludge may be of some concern.

- Other indicator parameters including oil and grease, total organic carbon (TOC), and dissolved solids are also reduced through the activated sludge system. Appendix A shows the various influent and effluent values along with the respective removal percentages.

5.0 ENGINEERING DESIGN CONSIDERATIONS

Groundwater Samples

The site chemicals of interest were primarily coal tar and creosote based chemicals along with some conventional pollutants and metals. Site groundwater was a composite sample from wells OW-10 and OW-11 located in the formerly identified coke plant processing area. Characterization data on the groundwater quality is presented in Appendices 1 and 2 and in Table 3-1. The groundwater sampled initially on-site contained total polynuclear aromatic hydrocarbons (PAH) at about 71,400 ug/l, phenols (4-AAP) at about 8 mg/l, BOD at 325, COD at 580, oil and grease at 113 mg/l, arsenic at about 12 ug/l, lead at about 6 ug/l, and the pH was 7.2.

The groundwater settled relatively oil and solids free by simple gravity settling, leaving oil layers on top and on the bottom of the 55-gallon drums with a clear middle supernatant layer. Table 4-1 presents the results of gravity settling versus polymer addition for oil/water phase separation testing. Gravity settling achieved an 86 percent decrease of the oil and grease present in the groundwater sample tested. The methylene chloride extractables concentration was reduced 70 percent, and total PAH concentration was reduced 73 percent from initial groundwater concentrations.

Polymer testing found that two combinations of Drew Chemical Company's polymers successfully flocculated the oil phase in the groundwater into a dense stable sludge. These polymers and the dosages utilized were:

Amerfloc 10 @ 300 ppm
Amerfloc 5260 @ 4 ppm
and
Amerfloc 10 @ 300 ppm
Amerfloc 5278 @ 4 ppm

The volume of wet sludge generated from these two polymer tests was 11.2 gallons per 1000 gallons of groundwater polymer treated (1.12 volume percent). This sludge dried at 103°C was 0.07 pounds of dry weight sludge per 1000 of groundwater polymer treated. Polymer treatment achieved 90 percent oil and grease removal and 79 percent methylene chloride extractables removal from groundwater

concentrations. Due to the added cost of polymers, and only slightly better removal rates, it was decided to use gravity settled groundwater supernatant in laboratory testing.

Soil Samples

Site soil samples were collected from soil boring area A-04 identified as an old creosote dumping area, between soil borings A04-SB01 and A04-SB02. The accomplished objective was to obtain site soil which contained the site chemicals of interest at elevated concentrations. The PAH concentration of the soil sampled was as high as 8 grams of total PAH per kilogram of soil (0.8%). PAH concentrations varied widely between soil samples analyzed, despite the good sampling, and analytical techniques employed. This variation is due to the heterogeneous nature of a soil matrix and to analyzing contaminated soils with sensitive analytical techniques which measure concentrations in the parts per billion range.

As an attempt to obtain the best representation of average soil PAH concentrations, six sets of measured untreated site soil PAH data were entered into a statistical computer program. The average mean PAH concentration obtained from the statistical analyses was about 3.7 grams of total PAH per kilogram of soil (0.37%). Table 4-5 presents the statistical summary of the measured site soil PAH concentrations.

Chemical Oxidation Treatment

Chemical oxidation testing using ozone in conjunction with ultraviolet light was performed on site groundwater samples. Initially an ozone/UV screening run was performed using TOC, phenols (4-AAP), naphthalene, and pH as treatment indicator parameters, to pick the optimum ozone dosage to apply. The results of the screening run showed that a 10 minute ozone/UV exposure time (285 mg ozone/liter groundwater) was optimal. Phenols (4-AAP) were reduced almost 99 percent from influent concentrations and the ozone utilization was 59 percent of the total ozone applied to the groundwater sample.

The first order reaction rates (K rates) were calculated, for the phenols (4-AAP) = -0.0077 and naphthalene = -0.0046. These negative K rates show that reduction of

the measured parameters occurred during testing. Appendix 5 presents the complete results of the ozone screening run and Appendix 6 presents the K rate calculations.

A final ozone/UV sampling run was performed at the 10 minute exposure time chosen from the screening run test (285 mg 0_3 per liter groundwater). The ozone utilization efficiency was almost identical to that obtained in the screening run test at 57 percent. The phenols (4-AAP) reduction obtained after 10 minutes of ozone/UV treatment was also reproduced with about 98 percent obtained.

The site chemicals of interest were analyzed for in the ozone/UV treated effluent. The pH measured in the influent was 6.7 and 6.4 in the treated effluent. Little or no effect was seen on the conventional pollutants (except phenol) and on the metals. Total PAH concentration was reduced 52 percent in the ozone/UV treated effluent. The effluent and influent groundwater were toxic in the Microtox™ bioassay test method, which uses luminescent marine bacteria as the test organisms.

Activated Carbon Treatment

Keystone performed isotherm testing on the site groundwater using Calgon Corporations F-300 granular activated carbon, pulverized so that 95 wt % passed through a 325 mesh screen.

The maximum adsorptive capacity for the F-300 carbon treating site groundwater was estimated based upon isotherm test results and the concentrations of chemicals present in the groundwater. Based upon the groundwater concentration of naphthalene at 2.74 mg/l, the estimated carbon usage from the isotherm testing is 9.85 pounds per 1000 gallons of groundwater treated. The carbon usage based upon the phenols (4-AAP) groundwater concentration of 7.45 mg/l, is 4.67 pounds of carbon per 1000 gallons of groundwater treated. The estimated carbon usage rate for the groundwater TOC concentration of 56 mg/l, is 2.08 pounds per 1000 gallons of groundwater treated.

The Calgon Corporation's Pittsburgh Pennsylvania laboratory was contracted to perform their accelerated carbon testing (ACT) program on a sample of site groundwater provided to them by Keystone. The Accelerated Column Test (ACT)

report issued from the Calgon Corporation's Pittsburgh, Pennsylvania laboratory is presented in Appendix 9a. The ACT used F-300 granular activated carbon and simulatd a carbon column system. Since no projected flow rate of pumped site groundwater, or any permit limits were available at the time of this treatability testing. Keystone specified the following conditions to Calgon for the ACT: a 15 minute empty bed contact time, the treatment indicator parameters and example treatment objectives of; TOC = 30 ppm, phenols (4AAP) = 0.5 ppm, and naphthalene = 0.5 ppm.

Table 4-3a summarizes the results of the activated carbon work performed by both Keystone and Calgon. The predicted carbon usage estimates generally agree between Calgon's ACT and Keystone's isotherm tests. The predicted carbon usages were based upon testing of a gravity settled composite sample of site groundwater from Wells OW-10 and OW-11:

TOC	=	2.08 to 2.5 #/m
Phenols (4AAP)	=	2.75 to 4.67 #/m
Naphthalene	=	0.85 to 1.0 #/m

where #/m is pounds of F-300 activated carbon used per 1000 gallons of site groundwater treated.

<u>Soil Washing</u>

Bench scale soil washing testing was performed by Keystone using the surface and subsurface soil samples collected from the site. The soil washing involved mechanical energy in the form of violent mixing to contact the soil with washing solutions containing surfactants, to free the trapped oil and grease type contaminants from the soil samples. A battery of soil washing experiments were performed and the results from the three most successful ones for both the surface and subsurface soil samples are presented in Tables 4-5 and 4-6. Over 96 percent removals for oil and grease, and methylene chloride extractables were obtained in these six soil washing experiments.

Conditions of the most successful screening run soil washing tests were chosen to run a final soil washing test on each of the soil samples - surface and subsurface. The analyses were identical to the screening run parameters except that PAH analyses

were also included. Results from the final soil washing tests are presented in Tables 4-7 and 4-8. The high percent removals obtained in the screening runs for oil and grease, and methylene chloride extractables were duplicated in the final runs. Additionally PAH removals obtained in the surface soils were 77 percent, and in the subsurface soil run over 99 percent, from the statistical mean PAH concentration obtained for the raw untreated soils.

Conditions for the final soil washing tests were two 45 minute washing cycles followed by one 10 minute rinse cycle. A wash cycle consisted of a 15 minute mixing time followed by a 30 minute washing/foaming time. Each final run utilized 500 grams of soil in 2500 mls of warm tap water. The amount of surfactants added in the first wash was decreased 50 percent for the second washing cycle. The type and amounts of surfactants used are listed on each table of results previously identified.

In Situ Soil Bioreclamation/Soil Columns

A bench scale soil biodegradation experiment was performed for 8 weeks to evaluate the feasibility of biologically treating soils on-site. The experiment involved pumping site groundwater upflow through packed soil columns at a flowrate which simulated the permeability of site soils, thus simulating the saturated soil zone on-site. The soil columns were supplied nutrients and a sludge seed, as well as maintaining proper environmental conditions for enhancing biological degradation of the organics present in site soil and groundwater samples. One column was operated aerobically, one anaerobically, and one served as a control column.

Results of the soil column effluent samplings are presented in Tables 4-11 through 4-13. The results indicate that the water phase PAH constituents were biologically degraded, with an increasing degradation rate towards the end of the eight week study, once the microbial population was acclimated and well established.

The control column effluent data showed that naphthalene was consistently being washed out of the soil column, with an average concentration of 824 ug/l. The aerobic and anaerobic soil column effluents contained less PAH concentrations than that present in the control column's effluent, indicating that biological degradation of the influent groundwater PAHs was occurring. The control column received no nutrients or sludge seed and was fed only tap water, thus the PAHs present in the

control column's effluent was due solely to the PAHs solubilizing off the column's soil and into the effluent. The large majority of the PAH's present in the control column's effluent were the lower ring, lower molecular weight PAH's as would be expected due to their relatively higher solubility in water.

The anaerobic soil column's effluent contained 78 percent less PAHs initially and by week #8, 92 percent less than the control's. The percentage of 2 and 3 ring PAHs in the anaerobic columns effluent showed a decreasing effect each sampling during the study, indicating that more efficient biodegradation of the soluble PAH's was occurring as the biological population became acclimated and more established within the soil column.

The aerobic soil column effluent data also shows that PAH biodegradation was occurring in the soil column, but at a slightly lesser rate than that obtained in the anaerobic column. The initial groundwater PAH concentration was reduced 56 percent in the aerobic soil column's effluent in the first sampling, and it increased to a 78 percent reduction of influent PAH concentration by the last sampling in week #8. The relative proportion of effluent PAHs which were more soluble (the 2 and 3 ring components) decreased from 62 percent initially to 16 percent by week #8, indicating that this microbiological population also increased and became more efficient at degrading the soluble PAH components after eight weeks of operation.

The soil phase of each column was sampled twice, initially upon loading and at the end of the 8 week study. The results are presented in Appendix 12 as received from Keystone's Monroeville laboratory, and in Tables 4-14 through 4-16, corrected to a dry weight basis. The soil results varied widely due to the heterogeneous nature of the soil matrix. The wide variation of concentrations measured for the site chemicals of interest made it too uncertain to attempt to draw any conclusions concerning the soil column performance with regards to the sol phase.

Slurry Reactors

As part of the biological degradation work performed by Keystone on site soil and groundwater samples, two biological slurry reactors were tested. These slurry reactors, also called suspended growth biological reactors, each contained a slurry of

site soil suspended in site groundwater by an electric stirrer. One reactor was operated in the aerobic mode, the other anaerobically.

Each reactor contained 56 percent by weight of area A-04 subsurface soil and 44 percent by weight of site groundwater, to form a total slurry volume of 2500 mls. Both reactors were supplied nutrients and an electron acceptor in the form of either oxygen in the aerobic, or nitrate in the anaerobic reactor. Test kit measurements indicated that a consistent usage of both nutrients and electron acceptors occurred, and that the desired environmental conditions for biological growth were maintained.

The aerobic reactor experienced several unexpected violent foaming incidences during the 4-week study. Commercial antifoam products were needed to subdue this foaming. As a result of the reactor foaming an estimated 1/3 of the reactors groundwater phase was lost and was replaced by tap water.

The soil and water phases were separated at the end of the four week study, and each was submitted to Keystone's Monroeville laboratory for analyses of: pH, percent solid, and PAH. The water phase results showed a decrease in PAH concentration for both reactors. The aerobic reactor achieved a 66 percent decrease, and the anaerobic an 88 percent decrease. Results from the soil phase were inconclusive with the aerobic reactor showing a decrease and the anaerobic reactor showing an increase in total soil PAH concentrations. The uncertainty involved in the soil PAH analyses due to the wide range of concentrations measured made it difficult to identify any trends for the slurry reactors performance with regards to the soil phase.

The results from this slurry reactor work are presented in Appendix 13, as received by Keystone's Monroeville laboratory, and in Table 4-17 corrected to a dry weight basis and compared to the statistical mean soil PAH concentration generated by the statistics program.

Activated Sludge Co-Treatability Study

The concept of treating contaminated groundwater jointly with domestic sanitary wastewaters at a publicly owned treatment works (POTW) was tested in a separate project by Keystone in 1987 on a pilot plant scale. This study is used for comparison

to the South Calvalcade site due to the majority of the same chemicals of interest being present in the groundwater tested in the pilot study.

Specifically the study entailed treating two groundwaters containing coal tar related chemicals of interest. One was collected from a former manufactured gas plant site, where formerly "town" gas was produced for lighting and heating from coal or oil. The second groundwater was more highly contaminated with coal tar chemicals from a former coke plant operations. The groundwater quality and the chemicals of interest are presented in Tables 4-18 and 4-19. The POTW process simulated employed activated sludge treatment and treated an average daily flow of 1 million gallons per day. A control reactor was also operated as a baseline for comparison, and it received only POTW influent wastewater feed.

Operating conditions for the three pilot plant reactors simulated the POTW as closely as possible. The solids retention time (SRT) was maintained at about 13.5 days. The hydraulic retention time (HRT) was about 8 hours. The pilot plant operated for 50 days, with steady state conditions assumed during the last 10 days of operation. At this assumed steady state time the initial activated sludge seed taken from the POTW was 87 percent "washed out" from the pilot plant reactors. Thus the sludges in each of the three reactors were representative of the long term sludge which would be obtained from treating each of the respective influent wastewaters tested.

The results of the clarified effluent quality obtained from these three pilot reactors are listed in Table 4-20. Table 4-21 presents the PAH mass balance for the pilot reactors sludges, and Table 4-22 presents analyses for the chemicals of interest in the three sludges.

A summary of the results presented in these tables is presented here and in the report. All three reactors produced the same quality effluent with regards to conventional, inorganic, volatile aromatics, and metals chemical parameters. In terms of phenolics and total PAH, the coke plant site reactor showed slightly higher effluent concentrations. These higher effluent results for the coke plant reactor effluent were below Best Available Technology (BAT) treated discharge standards recently set for the organic chemicals industry (52 Federal Register 42522, November 1987).

Based upon steady-state air monitoring results, the coke p'ant reactor was the only one of the three reactors which had measurable aeration tank volatilization of benzene, toluene, acenaphthalene and naphthalene.

A mass balance calculation on the wasted sludge from the reactors, presented in Table 4-21, indicates that the coke plant reactor's sludge contained greater amounts of volatile aromatics, total phenolics, and total PAH components than the control or MGP reactors.

The metals concentration of the wasted activated sludge for all three units was approximately the same. The results of the analyses performed on the wasted sludges are presented in Table 4-22.

In summary, the results of this study support that the addition of MGP type groundwaters into municipal wastewater treatment plants should result in non-measurable effects in terms of activated sludge treatment performance, and nonsignificant effects in terms of treated discharge water quality. The South Calvalcade groundwater is less concentrated in the chemicals of interest than was the coke plant wastewater which was successfully treated at a 20 percent by volume flowrate in the pilot experiment.

Keystone - Data Base

Appendix A presents 19 cases of successful application of the activated sludge treatment process from Keystone's files. Generally the case studies presented treated similar chemicals of interest as are present at the South Calvalcade site, but they were usually treating process wastewaters which contained much higher concentrations of these chemicals of interest than are present in South Calvalcade groundwater.

Examples given include activated sludge treatment of coke plant, tar plant, and creosote wood preservation plant wastewaters. These wastewaters contained such chemicals of interest as: phenolics, PAH, benzene, toluene, xylene, oil and grease, ammonia, and some metals. Operating conditions of the treatment processes are

given in Appendix A, along with influent and effluent concentrations and percent removal rates obtained. A summary of results obtained is presented in the report.

REFERENCES

1 "Newport, Store D Site Conceptual Design of an In-Situ Biodegradation System," Prepared by Keystone Environmental Resources, Inc., Monroeville, Pennsylvania, In Progress.

2 "Newport, Store D Site Groundwater Collection and Recharge System for Future In-Situ Biodegradation," Prepared by Keystone Environmental, Inc., Monroeville, Pennsylvania, September 1987.

3 "Wastewater Characterization/Treatability Study Report for Koppers Company, Inc., Feather River Plant," Prepared by Keystone Environmental Resources, Inc., Monroeville, Pennsylvania, June 1986.

4 Gibson, Subramanian, Microbial Degradation of Organic Compounds, Microbiology Series, Volume 13, Marcel Delker, Inc., New York, New York, 1984.

5 Sims, R.C. 1982. Land Treatment of Polynuclear Aromatic Compounds. Ph.D. dissertation. Dept. Biol. Agr. Eng., No. Carolina State Univ., Raleigh, N.C.

6 Overcash, M. R. and Pal, D. 1979. Design of Land Treatment Systems for Industrial Wastes - Theory and Practice. Ann Arbor Science Publishers, Inc., Ann Arbor, MI.

7 Clark, F.M. and Fina, L. R., Arch. Biochem. Biophys. 36:26 (1952).

8 Taylor, B.F., Campbell, W. L. and Chinoy, I. J. Bacteriol. 102:430 (1970).

APPENDIX 1

ON-SITE COMPOSITE SAMPLE OF WELL OW-10 AND OW-11 COLLECTED ON NOVEMBER 18, 1987

SPECTRIX MONROEVILLE

TABLE OF CONTENTS

PRODUCED ON 12/10/87 AT 13:25 PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
87110468	OW-10&11	QA/QC SAMPLES	11/18/87	11/19/87	M8711074
87110469	FB	QA/QC SAMPLES	11/18/87	11/19/87	M8711074
87110470	TB	QA/QC SAMPLES	11/18/87	11/19/87	M8711074

007993

SPECTRIX MONROEVILLE

ABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 12/10/87 AT 13:28 PAGE

SAMPLE #	RSLT. LNE		SOURCE
BIOCHEMICAL OXYGEN DEMAND (5 DAY, TOTAL)			
87110468	BOD, mg/L	325	OW-10&11
87110469	BOD, mg/L	<1.00	FB
87110470	BOD, mg/L	<1.00	TB
CHEMICAL OXYGEN DEMAND (TOTAL)			
87110468	COD (Total), mg/L	580	OW-10&11
87110469	COD (Total), mg/L	50.0	FB
87110470	COD (Total), mg/L	<10.0	TB
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
87110468	Oil & Grease, mg/L	113	OW-10&11
87110469	Oil & Grease, mg/L	<6.00	FB
87110470	Oil & Grease, mg/L	<5.00	TB
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
87110468	Phenol, mg/L	8.31	OW-10&11
87110469	Phenol, mg/L	<0.005	FB
87110470	Phenol, mg/L	<0.005	TB
TOTAL KJELDAHL NITORGEN			
87110468	TKN as N, mg/L	3.59	OW-10&11
87110469	TKN as N, mg/L	<1.00	FB
87110470	TKN as N, mg/L	<1.00	TB
TAL ORGANIC CARBON			
7110468	TOC, mg/L	63.4	OW-10&11
87110469	TOC, mg/L	<1.00	FB
87110470	TOC, mg/L	<1.00	TB
TOTAL PHOSPHATE			
87110468	Total PO4, mg/L	<0.100	OW-10&11
87110469	Total PO4, mg/L	<0.100	FB
87110470	Total PO4, mg/L	<0.100	TB
pH			
87110468	pH, units	7.2	OW-10&11
87110469	pH, units	8.5	FB
87110470	pH, units	7.8	TB

007994

007994

SPECTRIX MONROEVILLE

ABLE 2: SUMMARY OF METALS DATA — PRODUCED ON 12/10/87 AT 13:28 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
ANTIMONY			
87110468	Antimony, ug/L..... :	<60.0	OW-10&11
87110469	Antimony, ug/L..... :	<60.0	FB
87110470	Antimony, ug/L..... :	<60.0	TB
ARSENIC			
87110468	Arsenic, ug/L..... :	11.7	OW-10&11
87110469	Arsenic, ug/L..... :	<10.0	FB
87110470	Arsenic, ug/L..... :	<10.0	TB
BERYLLIUM			
87110468	Beryllium, ug/L..... :	<5.00	OW-10&11
87110469	Beryllium, ug/L..... :	<5.00	FB
87110470	Beryllium, ug/L..... :	<5.00	TB
CADMIUM			
87110468	Cadmium, ug/L..... :	<5.00	OW-10&11
87110469	Cadmium, ug/L..... :	5.10	FB
87110470	Cadmium, ug/L..... :	<5.00	TB
CHROMIUM			
87110468	Chromium, ug/L..... :	<10.0	OW-10&11
87110469	Chromium, ug/L..... :	<10.0	FB
87110470	Chromium, ug/L..... :	<10.0	TB
\PPER			
-/110468	Copper, ug/L..... :	<25.0	OW-10&11
87110469	Copper, ug/L..... :	<25.0	FB
87110470	Copper, ug/L..... :	<25.0	TB
LEAD			
87110468	Lead, ug/L..... :	6.20	OW-10&11
87110469	Lead, ug/L..... :	<5.00	FB
87110470	Lead, ug/L..... :	<5.00	TB
MERCURY			
87110468	Mercury, ug/L..... :	<0.200	OW-10&11
87110469	Mercury, ug/L..... :	<0.200	FB
87110470	Mercury, ug/L..... :	<0.200	TB
NICKEL			
87110468	Nickel, ug/L..... :	<40.0	OW-10&11
87110469	Nickel, ug/L..... :	<40.0	FB
87110470	Nickel, ug/L..... :	<40.0	TB
SELENIUM			
87110468	Selenium, ug/L..... :	<5.00	OW-10&11
87110469	Selenium, ug/L..... :	<5.00	FB
87110470	Selenium, ug/L..... :	<5.00	TB
SILVER			
87110468	Silver, ug/L..... :	<10.0	OW-10&11
87110469	Silver, ug/L..... :	<10.0	FB
87110470	Silver, ug/L..... :	<10.0	TB
THALLIUM			
-7110468	Thallium, ug/L..... :	<10.0	OW-10&11
110469	Thallium, ug/L..... :	<10.0	FB
87110470	Thallium, ug/L..... :	<10.0	TB

007995

007995

SPECTRIX MONROEVILLE

ABLE 2: SUMMARY OF METALS DATA PRODUCED ON 12/10/87 AT 13:28 PAGE

SAMPLE #	RSLT. LNE		SOURCE
ZINC			
87110468	Zinc, ug/L.....	<20.0	
87110469	Zinc, ug/L.....	<20.0	OW-10&11
87110470	Zinc, ug/L.....	<20.0	FB
			TB

007996

SPECTRIX MONROEVILLE

TABLE 3: SUMMARY OF PAH DATA

Sample: 87110468

Source: OW-10&11
Description: QA/QC SAMPLES

Date Collected: 11/18/87
Date Received: 11/19/87

Date Extracted: 11/20/87
Date Analyzed: 12/04/87

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

007997

Polynuclear Aromatic Hydrocarbons

Acenaphthene	6140
Acenaphthylene	1370
Anthracene	1640
Benzo(a)anthracene	892
Benzo(a)pyrene	329
Benzo(b)fluoranthene	518
Benzo(g,h,i)perylene	240
Benzo(k)fluoranthene	170
Chrysene	820
Dibenz(ah)anthracene	243
Fluoranthene	4840
Fluorene	3680
Indeno(123-cd)pyrene	96.5
Phenanthrene	9700
Pyrene	4390

Other Polynuclear Aromatic Compounds tested:

Carbazole	770
Naphthalene	35600

The above results are reported in ug/L .

All PAH identifications are from retention data only.

TABLE 3: SUMMARY OF PAH DATA

Sample: 87110469

Source: FB
Description: QA/QC SAMPLES

Date Collected: 11/18/87
Date Received: 11/19/87

Date Extracted: 11/20/87
Date Analyzed: 12/04/87

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

007698

Polynuclear Aromatic Hydrocarbons

Acenaphthene	<2.00
Acenaphthylene	<2.00
Anthracene	<0.500
Benzo(a)anthracene	<0.020
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(g,h,i)perylene	<0.050
Benzo(k)fluoranthene	<0.020
Chrysene	<0.150
Dibenz(ah)anthracene	<0.030
Fluoranthene	<0.200
Fluorene	<0.200
Indeno(123-cd)pyrene	<0.050
Phenanthrene	<0.500
Pyrene	<0.200

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L .

All PAH identifications are from retention data only.

SPECTRIX MONROEVILLE

TABLE 3: SUMMARY OF PAH DATA

Sample: 87110470

Source: TB
Description: QA/QC SAMPLES

Date Collected: 11/18/87
Date Received: 11/19/87

Date Extracted: 11/20/87
Date Analyzed: 12/04/87

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

007999

Polynuclear Aromatic Hydrocarbons

Acenaphthene	<2.00
Acenaphthylene	<2.00
Anthracene	<0.500
Benzo(a)anthracene	<0.020
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(g,h,i)perylene	<0.050
Benzo(k)fluoranthene	<0.020
Chrysene	<0.150
Dibenz(ah)anthracene	<0.030
Fluoranthene	<0.200
Fluorene	<0.200
Indeno(123-cd)pyrene	<0.050
Phenanthrene	<0.500
Pyrene	<0.200

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L .

All PAH identifications are from retention data only.

APPENDIX 2

MONROEVILLE COMPOSITE SAMPLE OF WELL OW-10 AND OW-11 SAMPLED ON DECEMBER 10, 1987

SPECTRIX MONROEVILLE

TABLE OF CONTENTS

PRODUCED ON 12/31/87 AT 12:29 PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
87120472	MSTC RAW	TREATABILITY STUDY	12/10/87	12/10/87	M8712071

008001

SPECTRIX MONROEVILLE

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 12/31/87 AT 12:30 PAGE

SAMPLE #	RSLT. LNE		SOURCE
BIOCHEMICAL OXYGEN DEMAND (5 DAY, TOTAL)			
87120472	BOD, mg/L.....	: 295	MSTC RAW
CHEMICAL OXYGEN DEMAND (TOTAL)			
87120472	COD (Total), mg/L.....	: 768	MSTC RAW
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
87120472	Oil & Grease, mg/L.....	: 144	MSTC RAW
PENTACHLOROPHENOL			
87120472	PCP, ug/L.....	: 1.80	MSTC RAW
TOTAL KJELDAHL NITROGEN			
87120472	TKN as N, mg/L.....	: 3.10	MSTC RAW
TOTAL ORGANIC CARBON			
87120472	TOC, mg/L.....	: 39.8	MSTC RAW
TOTAL PHOSPHATE			
87120472	Total PO4, mg/L.....	: 0.176	MSTC RAW
pH			
87120472	pH, units.....	: 7.4	MSTC RAW
METHYLENE CHLORIDE EXTRACTABLES			
87120472	Methylene Chloride, mg/L	: 253	MSTC RAW
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
87120472	Phenol, mg/L.....	: 7.82	MSTC RAW

The Pentachlorophenol identification is from retention data only.

008002

SPECTRIX MONROEVILLE

TABLE 2: SUMMARY OF METALS DATA

PRODUCED ON 12/31/87 AT 12:34 PAGE

SAMPLE #	RSLT. LNE		SOURCE
ANTIMONY			
87120472	Antimony, ug/L..... :	<60.0	MSTC RAW
ARSENIC			
87120472	Arsenic, ug/L..... :	15.4	MSTC RAW
BERYLLIUM			
87120472	Beryllium, ug/L..... :	<5.00	MSTC RAW
CADMIUM			
87120472	Cadmium, ug/L..... :	<5.00	MSTC RAW
CHROMIUM			
87120472	Chromium, ug/L..... :	<10.0	MSTC RAW
COPPER			
87120472	Copper, ug/L..... :	<25.0	MSTC RAW
LEAD			
87120472	Lead, ug/L..... :	<5.00	MSTC RAW
MERCURY			
87120472	Mercury, ug/L..... :	<0.200	MSTC RAW
NICKEL			
87120472	Nickel, ug/L..... :	<40.0	MSTC RAW
SELENIUM			
87120472	Selenium, ug/L..... :	<5.00	MSTC RAW
SILVER			
87120472	Silver, ug/L..... :	<10.0	MSTC RAW
THALLIUM			
87120472	Thallium, ug/L..... :	<10.0	MSTC RAW
ZINC			
87120472	Zinc, ug/L..... :	<20.0	MSTC RAW

008003

008003

SPECTRIX MONROEVILLE

TABLE 3: SUMMARY OF PAH DATA

Sample: 87120472

Source: MSTC RAW
Description: TREATABILITY STUDY

Date Collected: 12/10/87
Date Received: 12/10/87

Date Extracted: 12/14/87
Date Analyzed: 12/23/87

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008004

Polynuclear Aromatic Hydrocarbons

Acenaphthene	5280
Acenaphthylene	<200
Anthracene	864
Benzo(a)anthracene	856
Benzo(a)pyrene	322
Benzo(b)fluoranthene	461
Benzo(g,h,i)perylene	269
Benzo(k)fluoranthene	167
Chrysene	740
Dibenz(ah)anthracene	248
Fluoranthene	4140
Fluorene	2470
Indeno(123-cd)pyrene	118
Phenanthrene	6690
Pyrene	4610

Other Polynuclear Aromatic Compounds tested:

Carbazole	390
Naphthalene	11600

The above results are reported in ug/L .

All PAH identifications are from retention data only.

APPENDIX 3

PHYSICAL SEPARATION TEST RESULTS
COMPOSITE SAMPLE OF WELLS OW-10 AND OW-11
SAMPLED AT MONROEVILLE ON DECEMBER 11, 1987

SPECTRIX MONROEVILLE

TABLE OF CONTENTS

PRODUCED ON 12/31/87 AT 12:22 PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
87120551	PHYSICAL SEP	TREATABILITY STUDY	12/11/87	12/14/87	M8712084

008006

SPECTRIX MONROEVILLE

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 12/31/87 AT 12:22 PAGE

SAMPLE #	RSLT. LNE	SOURCE
METHYLENE CHLORIDE EXTRACTABLES		
87120551	Methylene Chloride, mg/L : 75.0	PHYSICAL SEP
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC		
87120551	Oil & Grease, mg/L..... : 19.9	PHYSICAL SEP
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)		
87120551	Phenol, mg/L..... : 7.72	PHYSICAL SEP
TOTAL ORGANIC CARBON		
87120551	TOC, mg/L..... : 60.5	PHYSICAL SEP

008007

SPECTRIX MONROEVILLE

TABLE 2: SUMMARY OF PAH DATA

Sample: 87120551

Source: PHYSICAL SEP
Description: TREATABILITY STUDY

Date Collected: 12/11/87
Date Received: 12/14/87

Date Extracted: 12/15/87
Date Analyzed: 12/25/87

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008008

Polynuclear Aromatic Hydrocarbons

Acenaphthene	414
Acenaphthylene	267
Anthracene	23.5
Benzo(a)anthracene	10.4
Benzo(a)pyrene	3.04
Benzo(b)fluoranthene	4.41
Benzo(g,h,i)perylene	2.43
Benzo(k)fluoranthene	1.57
Chrysene	8.20
Dibenz(ah)anthracene	1.71
Fluoranthene	57.9
Fluorene	198
Indeno(123-cd)pyrene	0.934
Phenanthrene	268
Pyrene	65.5

Other Polynuclear Aromatic Compounds tested:

Carbazole	94.7
Naphthalene	7790

The above results are reported in ug/L .

All PAH identifications are from retention data only.

APPENDIX 4

POLYMER TREATMENT TEST RESULTS
COMPOSITE SAMPLE OF WELL OW-10 AND OW-11
SAMPLED AT MONROEVILLE ON DECEMBER 29, 1987

SPECTRIX MONROEVILLE

TABLE OF CONTENTS

PRODUCED ON 01/06/88 AT 14:12 PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
87120915	S. C. JAR TEST RW	TREATABILITY STUDY	12/29/87	12/29/87	M8712166
87120916	S. C. JAR TEST 1	TREATABILITY STUDY	12/29/87	12/29/87	M8712166
87120917	S. C. JAR TEST 2	TREATABILITY STUDY	12/29/87	12/29/87	M8712166

008010

SPECTRIX MONROEVILLE

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 01/08/88 AT 09:00 PAGE

SAMPLE #	RSLT. LNE		SOURCE
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
87120915	Oil & Grease, mg/L...	: 156	S. C. JAR TEST RW
87120916	Oil & Grease, mg/L...	: 13.6	S. C. JAR TEST 1
87120917	Oil & Grease, mg/L...	: 23.1	S. C. JAR TEST 2
TOTAL ORGANIC CARBON			
87120915	TOC, mg/L.....	: 57.2	S. C. JAR TEST RW
87120916	TOC, mg/L.....	: 59.6	S. C. JAR TEST 1
87120917	TOC, mg/L.....	: 58.8	S. C. JAR TEST 2
METHYLENE CHLORIDE EXTRACTABLES			
87120915	Methylene Cl, mg/L...	: 136	S. C. JAR TEST RW
87120916	Methylene Cl, mg/L...	: 54.0	S. C. JAR TEST 1
87120917	Methylene Cl, mg/L...	: 48.0	S. C. JAR TEST 2

008011

APPENDIX 5

O_3/UV SCREENING RUN RESULTS

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS

PRODUCED ON 02/22/88 AT 10:07 PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88020146	03/UV SR 0 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022
88020147	03/UV SR 1 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022
88020148	03/UV SR 3 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022
88020149	03/UV SR 5 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022
88020150	03/UV SR 7 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022
88020151	03/UV SR 10 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022
88020152	03/UV SR 15 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022
88020153	03/UV SR 20 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022
88020154	03/UV SR 30 MIN	TREATABILITY STUDY	02/04/88	02/04/88	M8802022

008013

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1 SUMMARY OF ANALYTICAL DATA — PRODUCED ON 02/22/88 AT 10:07 — PAGE

SAMPLE #	RSLT. LNE			SOURCE
NAPHTHALENE				
88020146	Naphthalene, ug/L	:	65.1	03/UV SR 0 MIN
88020147	Naphthalene, ug/L	:	159	03/UV SR 1 MIN
88020148	Naphthalene, ug/L	:	459	03/UV SR 3 MIN
88020149	Naphthalene, ug/L	:	297	03/UV SR 5 MIN
88020150	Naphthalene, ug/L	:	231	03/UV SR 7 MIN
88020151	Naphthalene, ug/L	:	225	03/UV SR 10 MIN
88020152	Naphthalene, ug/L	:	83.3	03/UV SR 15 MIN
88020153	Naphthalene, ug/L	:	21.0	03/UV SR 20 MIN
88020154	Naphthalene, ug/L	:	<3.00	03/UV SR 30 MIN
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)				
88020146	Phenol, mg/L	:	4.95	03/UV SR 0 MIN
88020147	Phenol, mg/L	:	4.34	03/UV SR 1 MIN
88020148	Phenol, mg/L	:	2.99	03/UV SR 3 MIN
88020149	Phenol, mg/L	:	1.65	03/UV SR 5 MIN
88020150	Phenol, mg/L	:	0.746	03/UV SR 7 MIN
88020151	Phenol, mg/L	:	0.053	03/UV SR 10 MIN
88020152	Phenol, mg/L	:	0.032	03/UV SR 15 MIN
88020153	Phenol, mg/L	:	0.030	03/UV SR 20 MIN
88020154	Phenol, mg/L	:	0.017	03/UV SR 30 MIN
TOTAL ORGANIC CARBON				
88020146	TOC, mg/L	:	53.9	03/UV SR 0 MIN
88020147	TOC, mg/L	:	54.8	03/UV SR 1 MIN
88020148	TOC, mg/L	:	54.3	03/UV SR 3 MIN
88020149	TOC, mg/L	:	56.0	03/UV SR 5 MIN
88020150	TOC, mg/L	:	53.1	03/UV SR 7 MIN
88020151	TOC, mg/L	:	53.5	03/UV SR 10 MIN
88020152	TOC, mg/L	:	51.0	03/UV SR 15 MIN
88020153	TOC, mg/L	:	49.5	03/UV SR 20 MIN
88020154	TOC, mg/L	:	44.5	03/UV SR 30 MIN
pH				
88020146	pH, units	:	7.3	03/UV SR 0 MIN
88020147	pH, units	:	7.5	03/UV SR 1 MIN
88020148	pH, units	:	7.6	03/UV SR 3 MIN
88020149	pH, units	:	7.6	03/UV SR 5 MIN
88020150	pH, units	:	7.5	03/UV SR 7 MIN
88020151	pH, units	:	7.5	03/UV SR 10 MIN
88020152	pH, units	:	7.5	03/UV SR 15 MIN
88020153	pH, units	:	7.6	03/UV SR 20 MIN
88020154	pH, units	:	7.7	03/UV SR 30 MIN

The Naphthalene identifications are from retention data only.

008014

008014

APPENDIX 6

O_3/UV SCREENING RUN
FIRST ORDER DECAY RATE CONSTANT (K) CALCULATIONS

LEAST SQUARES REGRESSION FOR: PHENOL 4AAP

NUMBER OF DATA POINTS: 9

SLOPE:	-.0077
Y INTERCEPT:	1.1529
STANDARD DEVIATION:	1.0608
CORRELATION COEFFICIENT:	-.9091
COEFFICIENT OF DETERMINATION	.8265
COEFFICIENT OF DETERMINATION WITH b = 0	.4822

SLOPE =	-.0077 +/-	.0032 AT 95 PERCENT CONFIDENCE	
Y-INTERCEPT =	1.1529 +/-	1.2349 AT 95 PERCENT CONFIDENCE	
SLOPE WITH b = 0	-.0055 +/-	.0025	STD = 1.2924

INPUT DATA

X VALUE	Y VALUE	COMPUTED Y VALUE WITH 95% CONFIDENCE INTERVAL	
.0000	1.5990	1.1529 +/-	1.2349 Normal
		.0000 +/-	.0000 b = 0
24.7000	1.4680	.9625 +/-	1.1787 Normal
		-.1369 +/-	.0628 b = 0
85.4000	1.0950	.4943 +/-	1.0524 Normal
		-.4733 +/-	.2170 b = 0
168.0000	.5000	-.1427 +/-	.9177 Normal
		-.9311 +/-	.4269 b = 0
173.0000	-.2930	-.1813 +/-	.9113 Normal
		-.9588 +/-	.4396 b = 0
285.0000	-2.9370	-1.0450 +/-	.8363 Normal
		-1.5795 +/-	.7242 b = 0
505.0000	-3.4420	-2.7417 +/-	1.0819 Normal
		-2.7988 +/-	1.2832 b = 0
494.0000	-3.5060	-2.6569 +/-	1.0602 Normal
		-2.7379 +/-	1.2553 b = 0
854.0000	-4.0750	-5.4332 +/-	1.9746 Normal
		-4.7330 +/-	2.1700 b = 0

008016

LEAST SQUARES REGRESSION FOR: NAPHTHALENE

NUMBER OF DATA POINTS: 9

SLOPE:		-.0046
Y INTERCEPT:		5.8215
STANDARD DEVIATION:		.9847
CORRELATION COEFFICIENT:		-.8129
COEFFICIENT OF DETERMINATION		.6609
COEFFICIENT OF DETERMINATION WITH b = 0		4.4865

SLOPE = -.0046 +/- .0029 AT 95 PERCENT CONFIDENCE

Y-INTERCEPT = 5.8215 +/- 1.1463 AT 95 PERCENT CONFIDENCE

SLOPE WITH b = 0 .0064 +/- .0084 STD = 4.2816

INPUT DATA

X VALUE	Y VALUE	COMPUTED Y VALUE WITH 95% CONFIDENCE INTERVAL
.0000	4.1760	5.8215 +/- 1.1463 Normal .0000 +/- .0000 b = 0
24.7000	5.0690	5.7084 +/- 1.0942 Normal .1575 +/- .2079 b = 0
85.4000	6.1290	5.4305 +/- .9769 Normal .5446 +/- .7189 b = 0
168.0000	5.6590	5.0522 +/- .8519 Normal 1.0714 +/- 1.4142 b = 0
173.0000	5.5250	5.0293 +/- .8460 Normal 1.1033 +/- 1.4563 b = 0
285.0000	5.4160	4.5165 +/- .7763 Normal 1.8176 +/- 2.3991 b = 0
505.0000	4.4220	3.5091 +/- 1.0043 Normal 3.2206 +/- 4.2511 b = 0
494.0000	3.0440	3.5595 +/- .9842 Normal 3.1505 +/- 4.1585 b = 0
854.0000	1.0980	1.9110 +/- 1.8330 Normal 5.4464 +/- 7.1890 b = 0

008017

008017

APPENDIX 7

O_3/UV FINAL SAMPLING RUN RESULTS

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 03/29/88 AT 11:01 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88030072	03 EFFLUENT	TREATABILITY STUDY	03/03/88	03/03/88	M8803015
88030073	INFLUENT 2	TREATABILITY STUDY	03/03/88	03/03/88	M8803015

008019

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 03/29/88 AT 11:03 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
BIOCHEMICAL OXYGEN DEMAND (5 DAY, TOTAL)			
88030072	BOD, mg/L	390	03 EFFLUENT
88030073	BOD, mg/L	480	INFLUENT 2
CHEMICAL OXYGEN DEMAND (TOTAL)			
88030072	COD (Total), mg/L	302	03 EFFLUENT
88030073	COD (Total), mg/L	235	INFLUENT 2
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
88030072	Oil & Grease, mg/L	15.2	03 EFFLUENT
88030073	Oil & Grease, mg/L	14.9	INFLUENT 2
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88030072	Phenol, mg/L	0.024	03 EFFLUENT
88030073	Phenol, mg/L	1.48	INFLUENT 2
TOTAL KJELDAHL NITROGEN			
88030072	TKN as N, mg/L	7.64	03 EFFLUENT
88030073	TKN as N, mg/L	7.99	INFLUENT 2
TOTAL ORGANIC CARBON			
88030072	TOC, mg/L	57.6	03 EFFLUENT
88030073	TOC, mg/L	41.2	INFLUENT 2
TOTAL PHOSPHATE			
88030072	Total PO4, mg/L	8.20	03 EFFLUENT
88030073	Total PO4, mg/L	9.45	INFLUENT 2
pH			
88030072	pH, units	6.4	03 EFFLUENT
88030073	pH, units	6.7	INFLUENT 2

008020

008020

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 2: SUMMARY OF METALS DATA — PRODUCED ON 03/29/88 AT 11:03 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
ANTIMONY			
88030072	Antimony, ug/L.	<60.0	03 EFFLUENT
88030073	Antimony, ug/L.	<60.0	INFLUENT 2
ARSENIC			
88030072	Arsenic, ug/L.	15.8	03 EFFLUENT
88030073	Arsenic, ug/L.	15.3	INFLUENT 2
BERYLLIUM			
88030072	Beryllium, ug/L.	<5.00	03 EFFLUENT
88030073	Beryllium, ug/L.	<5.00	INFLUENT 2
CHROMIUM			
88030072	Chromium, ug/L.	10.1	03 EFFLUENT
88030073	Chromium, ug/L.	<10.0	INFLUENT 2
COPPER			
88030072	Copper, ug/L.	<25.0	03 EFFLUENT
88030073	Copper, ug/L.	<25.0	INFLUENT 2
LEAD			
88030072	Lead, ug/L.	<5.00	03 EFFLUENT
88030073	Lead, ug/L.	<5.00	INFLUENT 2
MERCURY			
88030072	Mercury, ug/L.	1.07	03 EFFLUENT
88030073	Mercury, ug/L.	<0.200	INFLUENT 2
NICKEL			
88030072	Nickel, ug/L.	<40.0	03 EFFLUENT
88030073	Nickel, ug/L.	<40.0	INFLUENT 2
SELENIUM			
88030072	Selenium, ug/L.	<5.00	03 EFFLUENT
88030073	Selenium, ug/L.	<5.00	INFLUENT 2
SILVER			
88030072	Silver, ug/L.	<10.0	03 EFFLUENT
88030073	Silver, ug/L.	<10.0	INFLUENT 2
THALLIUM			
88030072	Thallium, ug/L.	<10.0	03 EFFLUENT
88030073	Thallium, ug/L.	<10.0	INFLUENT 2
ZINC			
88030072	Zinc, ug/L.	112	03 EFFLUENT
88030073	Zinc, ug/L.	98.9	INFLUENT 2

008021

008021

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 3: SUMMARY OF PAH DATA

Sample: 88030072

Source: 03 EFFLUENT
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/09/88
Date Analyzed: 03/18/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008022

Polynuclear Aromatic Hydrocarbons

Acenaphthene	30.5
Acenaphthylene	<2.00
Anthracene	4.48
Benzo(a)anthracene	6.93
Benzo(a)pyrene	6.20
Benzo(b)fluoranthene	11.1
Benzo(g,h,i)perylene	11.1
Benzo(k)fluoranthene	4.27
Chrysene	13.2
Dibenz(ah)anthracene	15.4
Fluoranthene	57.6
Fluorene	7.23
Indeno(123-cd)pyrene	8.16
Phenanthrene	32.3
Pyrene	54.8

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 3: SUMMARY OF PAH DATA

Sample: 88030073

Source: INFLUENT 2
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/09/88
Date Analyzed: 03/19/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008023

Polynuclear Aromatic Hydrocarbons

Acenaphthene	56.3
Acenaphthylene	3.03
Anthracene	12.0
Benzo(a)anthracene	45.1
Benzo(a)pyrene	14.4
Benzo(b)fluoranthene	21.3
Benzo(g,h,i)perylene	16.8
Benzo(k)fluoranthene	8.10
Chrysene	43.5
Dibenz(ah)anthracene	24.9
Fluoranthene	101
Fluorene	18.6
Indeno(123-cd)pyrene	11.9
Phenanthrene	66.1
Pyrene	111

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L .

All PAH identifications are from retention data only.

MICROTOX(r) DATA SHEET

PHENOL STANDARD 16-25 MG/L, 3/7/88, TIME 5 MIN.

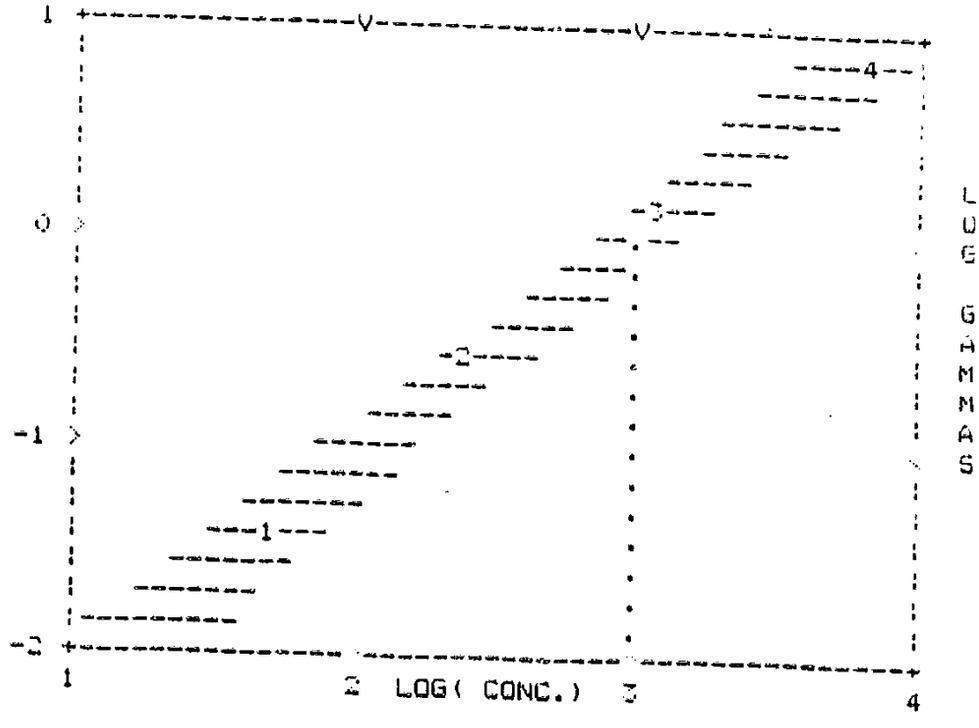
PAIR #	CONC.	Io/It	G-OBS	G-EST
1	5.680	85.0/ 65.0	0.250	0.259
2	11.360	86.0/ 52.0	0.581	0.561
3	22.730	85.0/ 36.0	1.257	1.216
4	45.450	89.0/ 24.0	2.545	2.633

BLANK Bo/Bt= 91 / 87
BLANK RATIO= 0.9560

EC 50	= 19.069	(17.328 TO 20.984)	
EC 20	= 5.512	(4.700 TO 6.464)	
EC 80	= 65.973	(54.318 TO 80.128)	

R =0.99921 SLOPE = 0.8953 INTERCEPT = +2.9481

PAIR #	RES.	PROB.
1	0.159	100
2	0.101	40
3	0.104	43
4	0.153	93



008024

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MICROTOX(r) DATA SHEET

PLICATE STANDARD, 3/7/88, 5 MIN.

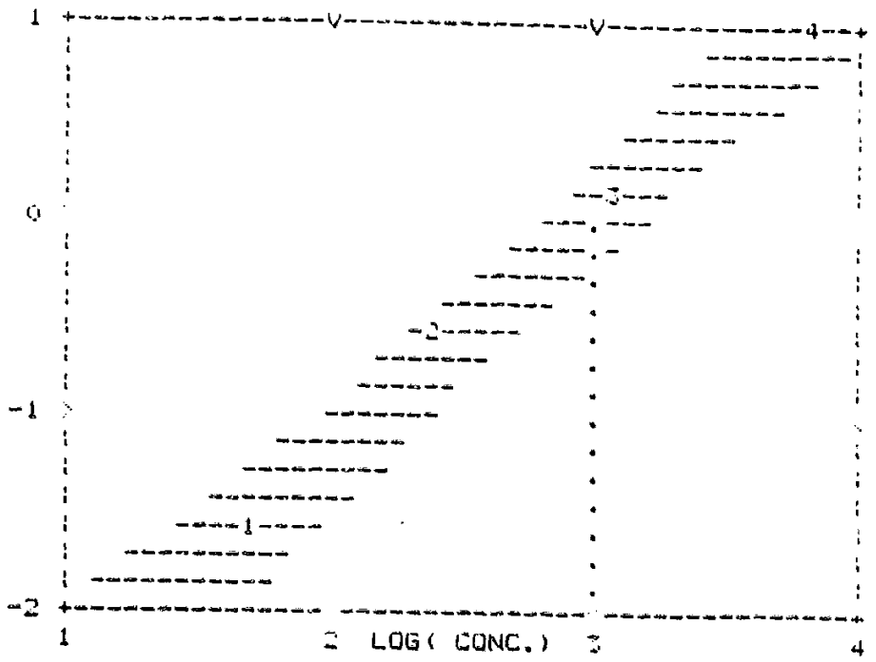
AIR #	CONC.	Io/It	G-OBS	G-EST
1	5.680	85.0/ 65.0	0.213	0.226
2	11.360	65.0/ 52.0	0.573	0.528
3	22.720	70.0/ 44.0	1.256	1.232
4	45.450	77.0/ 32.0	2.759	2.872

ANK Bo/Bt= 90 / 89
ANK RATIO= 0.9889

EC 50 = 19.154 (16.598 TO 22.104)
EC 20 = 6.183 (4.953 TO 7.719)
EC 80 = 59.336 (45.112 TO 78.045)

=0.99825 SLOPE = 0.8156 INTERCEPT = +2.9525

#	RES.	PROB.
1	0.241	100
2	0.148	38
3	0.154	41
4	0.229	90



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MICROTOX(r) DATA SHEET

9030072, COLL. 3/3/88 RUN 3/7/88, TIME 5 MIN.

AIR #	CONC.	Io/It	G-OBS	G-EST
1	5.680	94.0/ 58.0	0.549	0.558
2	11.360	96.0/ 44.0	1.085	1.043
3	22.720	91.0/ 30.0	1.899	1.952
4	45.450	88.0/ 18.0	3.672	3.651

BLANK Bo/Bt= 90 / 86
BLANK RATIO= 0.9556

EC 50 = 10.844 (9.848 TO 11.940)
EC 20 = 2.342 (1.860 TO 2.948)
EC 80 = 50.209 (43.096 TO 58.497)

R =0.99934 SLOPE = 1.1056 INTERCEPT = +2.3836

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MICROTOX(r) DATA SHEET

9030072, COLL. 3/3/88, RUN 3/7/88, TIME 15 MIN.

AIR #	CONC.	Io/It	G-OBS	G-EST
1	5.680	94.0/ 58.0	0.603	0.622
2	11.360	96.0/ 42.0	1.260	1.203
3	22.720	91.0/ 27.0	2.333	2.331
4	45.450	88.0/ 16.0	4.439	4.511

BLANK Bo/Bt= 90 / 89
BLANK RATIO= 0.9889

EC 50 = 9.761 (8.364 TO 10.477)
EC 20 = 2.190 (1.697 TO 2.826)
EC 80 = 40.010 (34.690 TO 46.146)

R =0.99923 SLOPE = 1.0478 INTERCEPT = +2.2366

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MICROTOX(r) DATA SHEET

9030072 DUP, COLL. 3/3/88, RUN 3/7/88, TIME 5 MIN.

AIR #	CONC.	Io/It	G-OBS	G-EST
1	5.680	94.0/ 62.0	0.497	0.476
2	11.360	69.0/ 38.0	0.793	0.985
3	22.730	38.0/ 10.0	2.753	2.041
4	45.450	86.0/ 18.0	3.719	4.225

BLANK Bo/Bt= 81 / 80
BLANK RATIO= 0.9877

EC 50	=	11.737	(6.440 TO 21.392)
EC 20	=	3.372	(0.942 TO 12.065)
EC 80	=	40.857	(16.913 TO 98.702)

R =0.97202 SLOPE = 0.8998 INTERCEPT = +2.4627

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MICROTOX(r) DATA SHEET

9030072 DUP, COLL. 3/3/88, RUN 3/7/88, TIME 15 MIN.

AIR #	CONC.	Io/It	G-OBS	G-EST
2	11.360	94.0/ 58.0	1.180	1.386
3	22.730	69.0/ 34.0	4.102	2.917
3	45.450	38.0/ 8.0	5.158	6.135
1	5.680	86.0/ 15.0	0.655	0.659

BLANK Bo/Bt= 81 / 87
BLANK RATIO= 1.0741

EC 50	=	8.704	(4.166 TO 18.187)
EC 20	=	2.579	(0.574 TO 11.584)
EC 80	=	29.380	(14.125 TO 61.108)

R =0.97024 SLOPE = 0.8775 INTERCEPT = +2.1638

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MICROTOX(r) DATA SHEET

8803007Z, COLL. 3/3/88, RUN 3/7/88, TIME 5 MIN, PREDIL 10X

PAIR #	CONC.	Io/It	G-OBS	G-EST
1	0.568	112.0/ 85.0	0.233	0.241
2	1.136	99.0/ 62.0	0.494	0.471
3	2.273	91.0/ 44.0	0.935	0.920
4	4.545	94.0/ 32.0	1.748	1.795

BLANK Bo/Bt= 93 / 87
BLANK RATIO= 0.9355

EC 50	=	2.477	(2.193 TO	2.796)
EC 20	=	0.590	(0.496 TO	0.702)
EC 80	=	10.390	(7.879 TO	13.701)

R =0.99899 SLOPE = 1.0344 INTERCEPT = +0.9069

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MICROTOX(r) DATA SHEET

8803007Z, COLL. 3/3/88, RUN 3/7/88, TIME 15 MIN, PREDIL 10X

PAIR #	CONC.	Io/It	G-OBS	G-EST
1	0.568	112.0/ 89.0	0.372	0.284
2	1.136	99.0/ 63.0	0.588	0.554
3	2.273	91.0/ 44.0	1.090	1.083
4	4.545	94.0/ 31.0	2.065	2.116

BLANK Bo/Bt= 93 / 94
BLANK RATIO= 1.0108

EC 50	=	2.091	(1.839 TO	2.378)
EC 20	=	0.500	(0.401 TO	0.623)
EC 80	=	8.746	(6.526 TO	11.721)

R =0.99867 SLOPE = 1.0322 INTERCEPT = +0.7377

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MICROTOX(r) DATA SHEET

88030073 DUP, COLL. 3/3/88, RUN 3/7/88, TIME 5 MIN, PREDIL 10X

PAIR #	CONC.	Io/It	G-OBS	G-EST
1	0.568	87.0/ 68.0	0.224	0.227
2	1.136	87.0/ 57.0	0.460	0.466
3	2.273	87.0/ 41.0	1.030	0.957
4	4.454	86.0/ 29.0	1.837	1.921

BLANK Bo/Bt= 92 / 88
BLANK RATIO= 0.9565

EC 50	=	2.369	(2.048 TO	2.742)
EC 20	=	0.625	(0.509 TO	0.767)
EC 80	=	8.988	(6.527 TO	12.377)

R =0.99846 SLOPE = 0.9617 INTERCEPT = +0.8627

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MICROTOX(r) DATA SHEET

88030073 DUP, COLL. 3/3/88, RUN 3/7/88, TIME 15 MIN, PREDIL 10X

PAIR #	CONC.	Io/It	G-OBS	G-EST
1	0.568	87.0/ 71.0	0.252	0.259
2	1.136	87.0/ 58.0	0.533	0.524
3	2.273	87.0/ 42.0	1.116	1.063
4	4.454	86.0/ 29.0	2.030	2.109

BLANK Bo/Bt= 92 / 94
BLANK RATIO= 1.0217

EC 50	=	2.140	(1.915 TO	2.391)
EC 20	=	0.550	(0.461 TO	0.657)
EC 80	=	8.319	(6.506 TO	10.638)

=0.99902 SLOPE = 0.9795 INTERCEPT = +0.7606

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MICROTOX INTERPRETATION SCALES

TOXICITY RATING	EC50	EC20
4 - VERY TOXIC	<10%	<1%
3 - TOXIC	>10% TO 50%	>1% TO 20%
2 - MILDLY TOXIC	>50% TO 75%	>20% TO 30%
1 - SLIGHTLY TOXIC	>75% TO 100%	>30% TO 40%
0 - NON TOXIC	>100%	>40%

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APPENDIX 8

ACTIVATED CARBON ISOTHERM TEST RESULTS

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 02/18/88 AT 14:42 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88010582	CI 0.0g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010583	CI 0.005g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010584	CI 0.01g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010585	CI 0.025g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010586	CI 0.05g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010587	CI 0.10g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010588	CI 0.20g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010589	CI 0.50g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010590	CI 1.0g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010591	CI 2.5g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010592	CI 5.0g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010593	CI 10.0g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160
88010594	CI 20.0g	TREATABILITY STUDY	01/28/88	01/29/88	M8801160

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KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 02/18/88 AT 14:45 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
NAPHTHALENE			
88010582	Naphthalene, ug/L...	: 2740	CI 0.0g
88010583	Naphthalene, ug/L...	: 3560	CI 0.005g
88010584	Naphthalene, ug/L...	: 784	CI 0.01g
88010585	Naphthalene, ug/L...	: 32.4	CI 0.025g
88010586	Naphthalene, ug/L...	: <3.00	CI 0.05g
88010587	Naphthalene, ug/L...	: <3.00	CI 0.10g
88010588	Naphthalene, ug/L...	: <3.00	CI 0.20g
88010589	Naphthalene, ug/L...	: <3.00	CI 0.50g
88010590	Naphthalene, ug/L...	: <3.00	CI 1.0g
88010591	Naphthalene, ug/L...	: <3.00	CI 2.5g
88010592	Naphthalene, ug/L...	: <3.00	CI 5.0g
88010593	Naphthalene, ug/L...	: <3.00	CI 10.0g
88010594	Naphthalene, ug/L...	: <3.00	CI 20.0g
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88010582	Phenol, mg/L.....	: 7.45	CI 0.0g
88010583	Phenol, mg/L.....	: 6.45	CI 0.005g
88010584	Phenol, mg/L.....	: 6.82	CI 0.01g
88010585	Phenol, mg/L.....	: 4.22	CI 0.025g
88010586	Phenol, mg/L.....	: 0.937	CI 0.05g
88010587	Phenol, mg/L.....	: 0.053	CI 0.10g
88010588	Phenol, mg/L.....	: 0.009	CI 0.20g
88010589	Phenol, mg/L.....	: <0.005	CI 0.50g
88010590	Phenol, mg/L.....	: <0.005	CI 1.0g
88010591	Phenol, mg/L.....	: <0.005	CI 2.5g
88010592	Phenol, mg/L.....	: <0.005	CI 5.0g
88010593	Phenol, mg/L.....	: <0.005	CI 10.0g
88010594	Phenol, mg/L.....	: <0.005	CI 20.0g
TOTAL ORGANIC CARBON			
88010582	TOC, mg/L.....	: 56.0	CI 0.0g
88010583	TOC, mg/L.....	: 47.0	CI 0.005g
88010584	TOC, mg/L.....	: 37.7	CI 0.01g
88010585	TOC, mg/L.....	: 17.3	CI 0.025g
88010586	TOC, mg/L.....	: 7.49	CI 0.05g
88010587	TOC, mg/L.....	: 3.95	CI 0.10g
88010588	TOC, mg/L.....	: 4.00	CI 0.20g
88010589	TOC, mg/L.....	: 5.61	CI 0.50g
88010590	TOC, mg/L.....	: 4.23	CI 1.0g
88010591	TOC, mg/L.....	: 3.78	CI 2.5g
88010592	TOC, mg/L.....	: 3.03	CI 5.0g
88010593	TOC, mg/L.....	: 2.96	CI 10.0g
88010594	TOC, mg/L.....	: 3.09	CI 20.0g

The Naphthalene identifications are from retention data only.

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KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 02/16/88 AT 14:45 — PAGE

SAMPLE #	RSLT. LNE			SOURCE
pH				
88010582	pH, units	:	7.5	CI 0.0g
88010583	pH, units	:	7.6	CI 0.005g
88010584	pH, units	:	7.6	CI 0.01g
88010585	pH, units	:	7.5	CI 0.025g
88010586	pH, units	:	7.6	CI 0.05g
88010587	pH, units	:	7.6	CI 0.10g
88010588	pH, units	:	7.6	CI 0.20g
88010589	pH, units	:	7.8	CI 0.50g
88010590	pH, units	:	7.8	CI 1.0g
88010591	pH, units	:	7.8	CI 2.5g
88010592	pH, units	:	8.0	CI 5.0g
88010593	pH, units	:	8.2	CI 10.0g
88010594	pH, units	:	8.2	CI 20.0g

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APPENDIX 9

CARBON ADSORPTION ISOTHERM PLOTS

TABLE 9-1

SOUTH CALVALCADE SITE
CARBON ADSORPTION ISOTHERM DATA

NAPHTHALENE

(m) Weight of Carbon (gram/100 ml solution)	(c) Concentration of Naphthalene In Solution (mg/l)	(x) Total Naphthalene Adsorbed (mg/l)	(x/m) Naphthalene Adsorbed Per Unit Weight (mg/gram carbon)
0 (control)	2.740	-	-
0.005	3.560	-	-
0.01	0.784	1.956	19.56
0.025	0.032	2.708	10.83
0.05	<0.003	>2.737	>5.47
0.1	<0.003	>2.737	>5.47
0.2	<0.003	>2.737	>5.47
0.5	<0.003	>2.737	>5.47
1	<0.003	>2.737	>5.47
2.5	<0.003	>2.737	>5.47
5	<0.003	>2.737	>5.47
10	<0.003	>2.737	>5.47
20	<0.003	>2.737	>5.47

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TABLE 9-1 (continued)

SOUTH CALVALCADE SITE
CARBON ADSORPTION ISOTHERM DATA

PHENOL

(m) Weight of Carbon (gram/100 ml solution)	(c) Concentration of Phenol In Solution (mg/l)	(x) Phenol Adsorbed (mg/l)	(x/m) Phenol Adsorbed Per Unit Weight (mg/gram carbon)
0 (control)	7.45	-	-
0.005	6.45	1.000	20.0
0.01	6.82	0.630	6.3
0.025	4.22	3.230	12.9
0.05	0.937	6.513	13.03
0.01	0.053	7.397	7.39
0.2	0.009	7.441	3.72
0.5	<0.005	>7.445	>1.49
1	<0.005	>7.445	>1.49
2.5	<0.005	>7.445	>1.49
5	<0.005	>7.445	>1.49
10	<0.005	>7.445	>1.49
20	<0.005	>7.445	>1.49

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TABLE 9-1 (continued)

SOUTH CALVALCADE SITE
CARBON ADSORPTION ISOTHERM DATA

TOC

(m) Weight of Carbon (gram/100 ml solution)	(c) Concentration of TOC In Solution (mg/l)	(x) TOC Adsorbed (mg/l)	(x/m) TOC Adsorbed Per Unit Weight (mg/gram carbon)
0 (control)	56.0	-	-
0.005	47.0	9.00	180
0.01	37.7	18.30	183
0.025	17.3	38.70	154.8
0.05	7.49	48.5	97.0
0.1	3.95	52.05	52.0
0.2	4.00	52.00	26.00
0.5	5.61	50.39	10.0
1	4.23	51.77	5.2
2.5	3.78	52.22	2.1
5	3.03	52.97	1.0
10	2.96	53.04	0.5
20	3.09	52.91	0.26

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TABLE 9-1 (continued)

SOUTH CALVALCADE SITE
CARBON ADSORPTION ISOTHERM DATA

pH

(m)

Weight of Carbon (gram/100 ml solution)	pH of Filtrate
0 (control)	7.5
0.005	7.6
0.01	7.6
0.025	7.5
0.05	7.6
0.1	7.6
0.2	7.6
0.5	7.8
1	7.8
2.5	7.8
5	8.0
10	8.2
20	8.2

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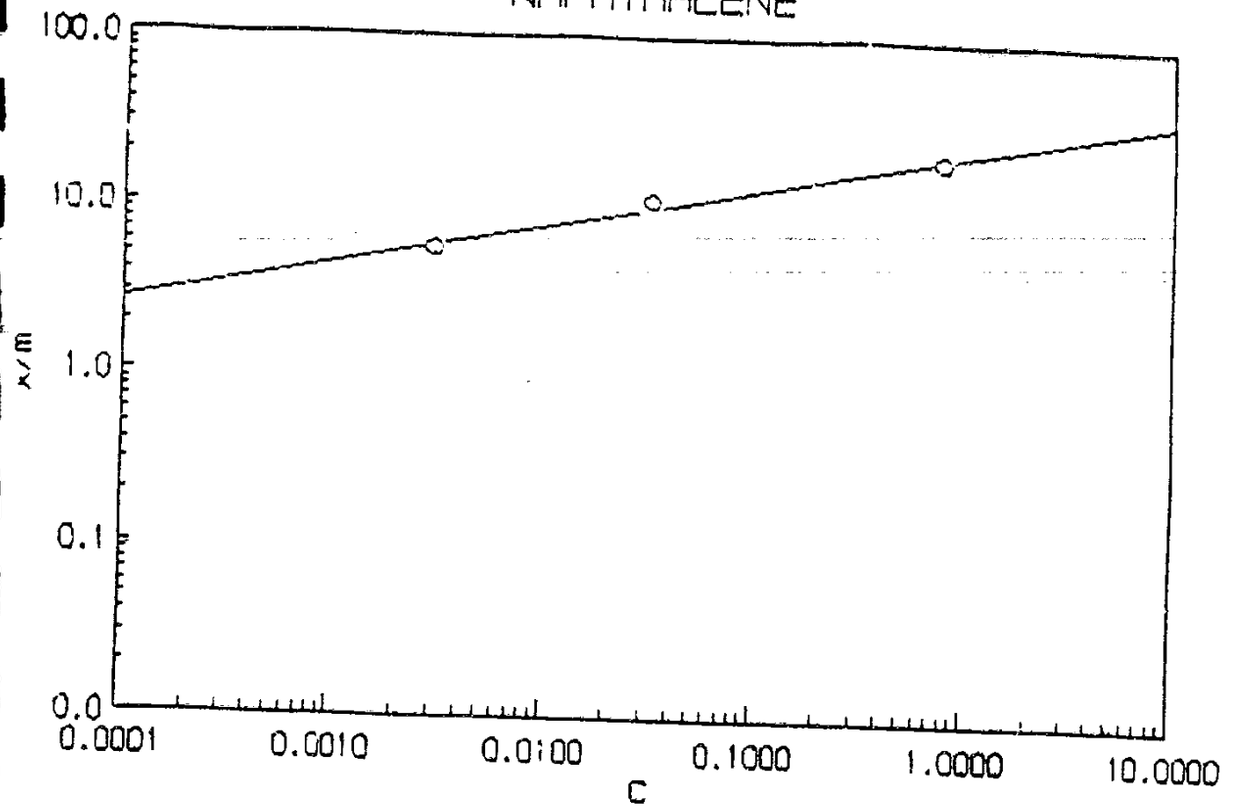
SOUTH CALVALCADE

CARBON ISOTHERMS

NAPHTHALENE



The regression formula for computing Y0 is :
Y0 = 0.42683
+1.13214 x ((X+4.00000)/5.00000)

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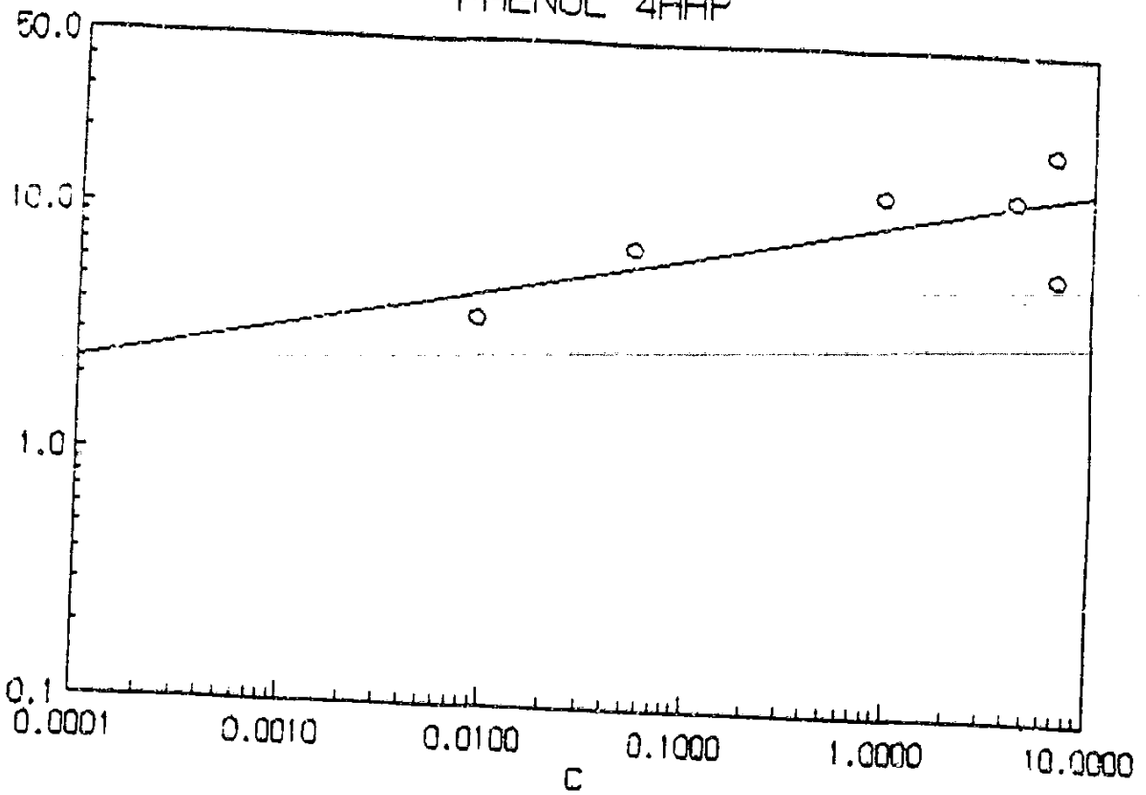
SOUTH CALVALCADE

CARBON ISOTHERMS

PHENOL 4AAP



The regression formula for computing Y0 is :
Y0 = 0.36604
+0.77859 x ((X+4.00000)/5.00000)

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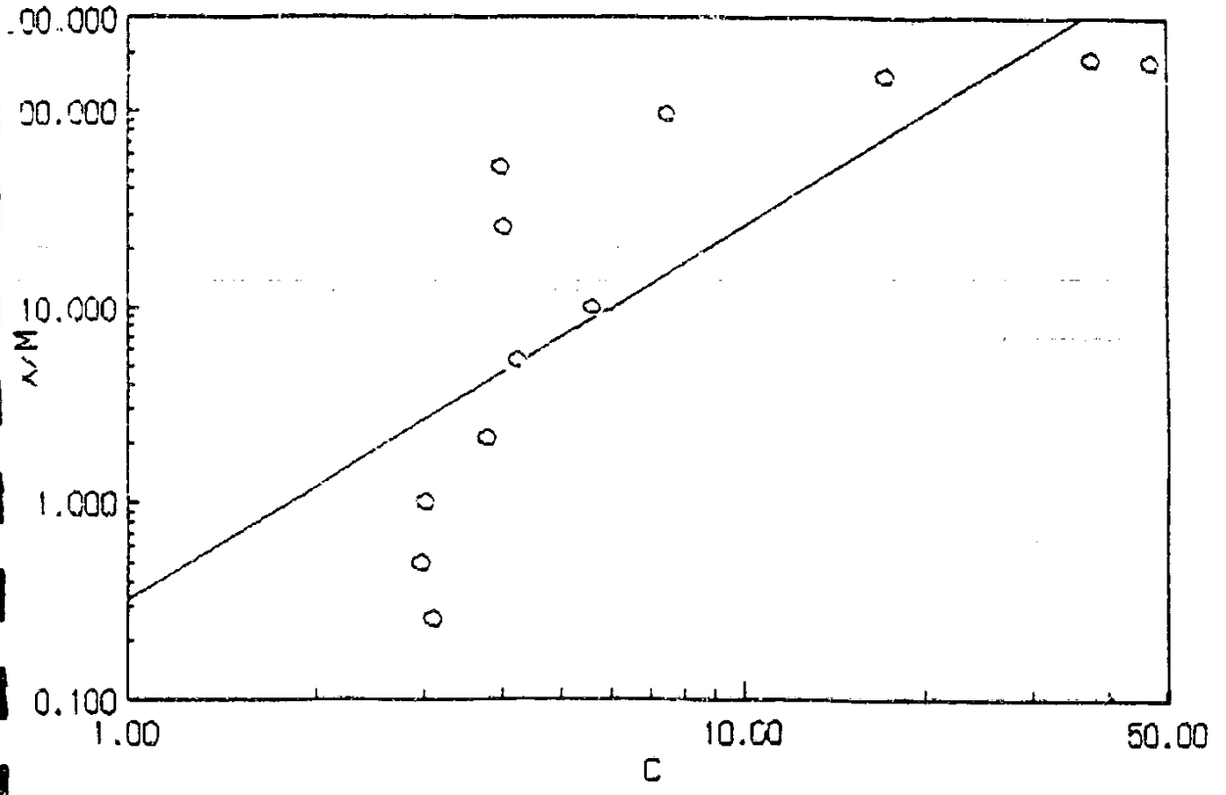
SOUTH CALVALCADE

CARBON ISOTHERMS

TCC

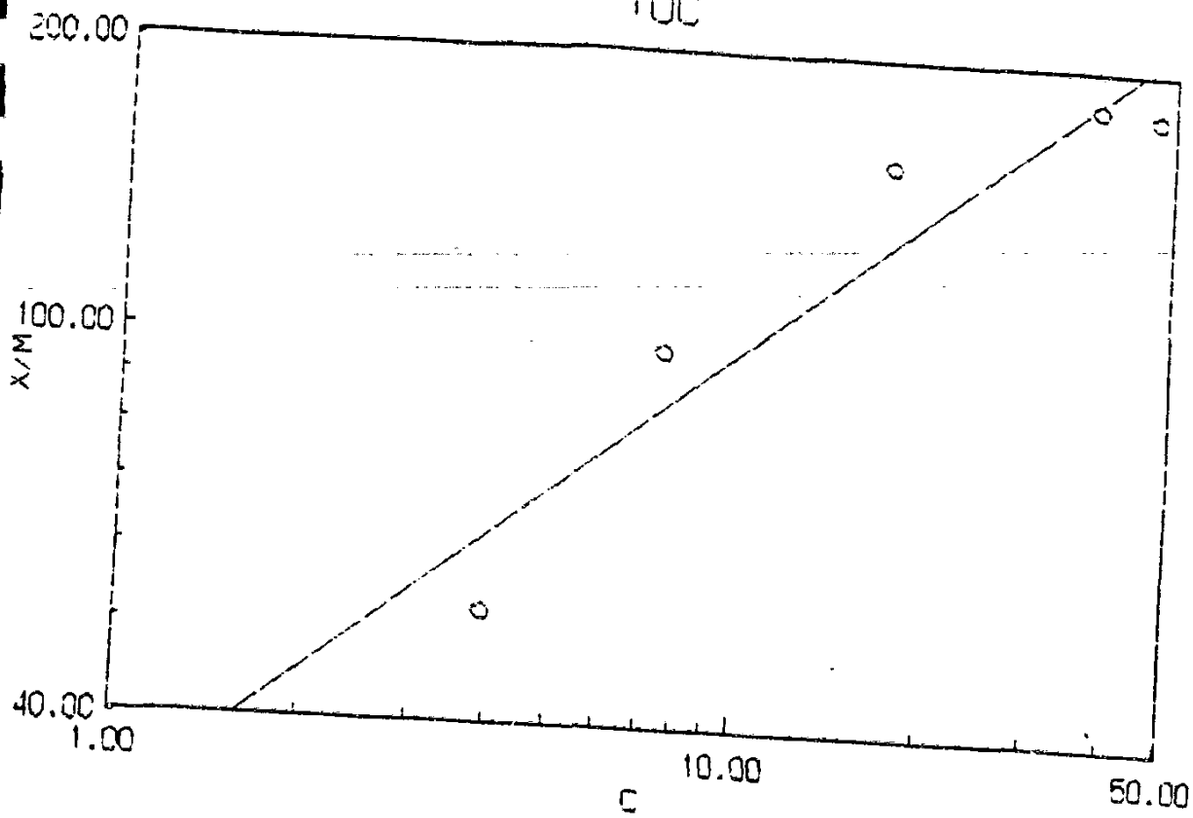


The regression formula for computing Y0 is :
Y0 = -0.50098
+3.24075 * ((X-0.00000)/1.69897)

SOUTH CALVALCADE

CARBON ISOTHERMS

TOC



The regression formula for computing Y0 is :

Y0 = 1.50365
+0.82474 x ((X-0.00000)/1.69897)

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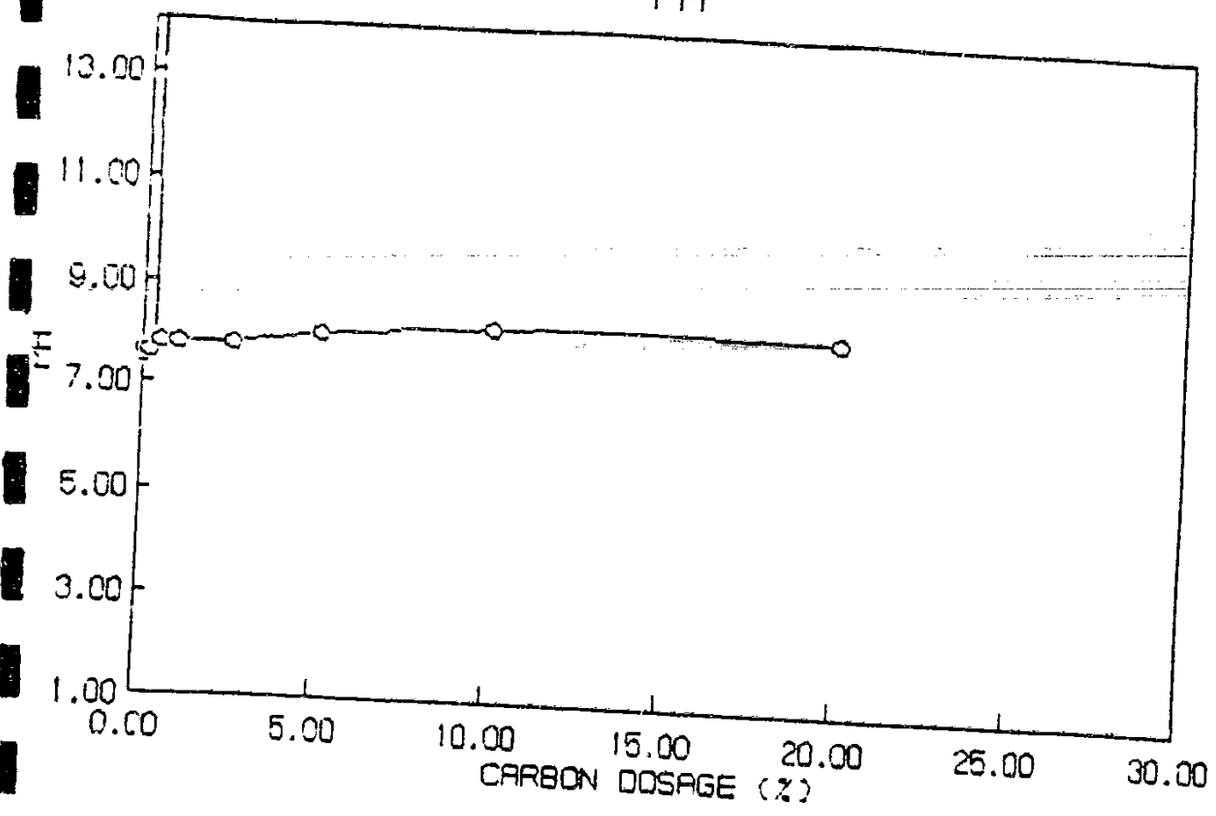
SOUTH CALVADE

CARBON ISOTHERMS

PH



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APPENDIX 9A

CALGON CORPORATION'S ACT REPORT

CALGON

CALGON CARBON CORPORATION

CALGON CARBON CORPORATION P.O. BOX 717 PITTSBURGH, PA 15230-0717 (412) 787-6700 TELEX 671 1837 CCC PGH

PANAFAX: 412-787-6713

787-6756

April 20, 1988

Mr. Mark Smock
KEYSTONE ENVIRONMENTAL COMPANY
440 College Park Drive
Monroeville, PA 15146

008046

Dear Mr. Smock:

Enclosed for your review are two (2) copies of the technical services report presenting the results of the Accelerated Column Test (ACT) study on samples of pretreated groundwater from your Cavalcade, Texas site.

Keystone Environmental has not yet determined the flow for the groundwater at the site. A 15 minute empty bed contact time (EBCT) simulates the following flow in Calgon Carbon's product lines that are backwashable.

Model	Vessel Diam.(ft.)	EBCT	Flow	Amount Carbon Per Adsorber	F-300 Backwash Flow Rate Req'd for 50% exp.
Mobile PAC	4 ft.	15 min.	24 gpm	1,340#	240 gpm
Model 2	4 ft.	15 min.	35 gpm	2,000#	240 gpm
Model 7½	7.5 ft.	15 min.	116 gpm	6,500#	840 gpm
Model 10	10 ft.	15 min.	356 gpm	20,000#	1500 gpm

The results of the ACT indicate that the phenolics will be the limiting factor, followed by TOC, and finally the naphthalene. Although the naphthalene initial concentration was below the treatment objective, significant breakthrough was achieved at 25 days of simulated time.

The following table lists initial concentration treatment objectives and carbon usage for each component:

		TOC	Phenols	Naphthalene
1)	Anticipated Initial Conc.	63 ppm	8 ppm	35 ppm
2)	Actual Initial Conc.	58 ppm	5.3 ppm	0.335 ppm
3)	Treatment Objective	30 ppm	0.5 ppm	0.5 ppm
4)	Using 2 Vessels in series anticipated carbon use rate	2.5#/M	2.75#/M gal.	1#/M gal. (to 50% breakthrough)

The following lists each previously mentioned carbon adsorption system with their carbon usage at the 15 min. EBCT.

	Model	Flow Rate	At 2.5#/M Gal. Carbon Use Rate	Change Out
1)	Mobile PAC	24 gpm	86.4#/day	24 days
2)	Model 3	35 gpm	126#/day	16 days
3)	Model 7.5	116 gpm	418#/day	24 days
4)	Model 10	356 gpm	1283#/day	16 days

In the report, air stripping is mentioned as a possible alternative. The design of an air stripping system will depend upon 1) each compound's air stripping factor; 2) economics of an air stripping system with a liquid phase carbon system for non-strippable compounds, and 3) if a vapor phase carbon system is needed for the vapor exhaust stream. Usually in groundwater cleanups involving phenolic compounds, air stripping is not used because the compounds are not air strippable.

Once Keystone Environmental determines the flow rate, firm pricing can be given for the appropriate adsorption system.

If you have questions or need further information, please feel free to contact Ron Moskal or myself.

Very truly yours,

CALGON CARBON CORPORATION

Gary H. Gunnerson
Applications Engineer

GHG:ah

cc: R. M. Moskal

008048

CONFIDENTIAL

CALGON CARBON CORPORATION

Technical Service Report No. 0188-28

Accelerated Column Test for Removal of TOC, Phenolics and Naphthalene from Groundwater Using F-300 GAC

008049

Prepared for:

Keystone Environmental, Inc.
Monroeville, PA

Author: P. A. Reiser
P. A. Reiser 6625

Investigator: P. A. Reiser

Date: April 4, 1988

COPY:
D. A. Biscan
V. A. Brunotts
S. D. Cifrulak
M. M. Clemens
R. M. Moskal
C. H. Gunnerson
F. F. Mendicino

KEYWORDS:
ACT
F-300
Groundwater
TOC
Phenol
Phenolics
Naphthalene

OBJECTIVE

Keystone Environmental, Inc. of Monroeville, PA submitted a sample of groundwater from a plant site in South Cavalcade, Texas for carbon treatability studies. The groundwater is contaminated with TOC, including phenolics and naphthalene. An ACT study was requested using Calgon Carbon's F-300 GAC, including monitoring the breakthrough of TOC, phenolics and naphthalene. Treatment objective for these three parameters had been set at 30 mg/L, 0.5 mg/L and 0.5 mg/L, respectively.

SUMMARY & CONCLUSIONS

An ACT study was conducted for TOC, phenolics and napthalene removal.

1. The treatment objective of 0.5 mg/L phenolics was achieved after simulation of 11.5 days operation and the predicted treatment of 0.58 million gallons of groundwater. The carbon achieved a usage rate of 3.43 lbs/1000 gallons. (Table I and Figure 1).

2. The treatment objective of 30 mg/L TOC was reached after simulation of 13.0 days of operation and the predicted treatment of 0.76 million gallons of groundwater. The carbon achieved an exhaustion rate of 2.62 lbs/1000 gallons. (Table I and Figure 2).

3. The naphthalene concentration of the filtered groundwater was less than the stated treatment objective. However, initial breakthrough of naphthalene was found after only 15.9 days of simulated operation. (Table I and Figure 3). The early naphthalene breakthrough could be attributable to the high concentration of solvents in the sample. High levels of volatile hydrocarbons (non-halogenated) were noted in the samples analyzed for naphthalene (Figure 4).

RECOMMENDATIONS

To obtain optimum GAC performance it is recommended that the groundwater be filtered for solids removal prior to treatment. In addition, it is probable that improved carbon performance would be achieved if the groundwater were air-stripped prior to treatment with GAC. This recommendation is based on the high level of volatile hydrocarbon contamination noted in the samples during the course of the gas chromatographic analysis for naphthalene (Figure 4).

DISCUSSION

The groundwater sample as received contained a significant amount of solids and required vacuum filtration through glass fiber filter paper prior to testing. Because of the well documented affinity of naphthalene and other PNA's for particulate matter, a filter pad containing the suspended solids from the sample was extracted with methanol and quantitively analyzed for naphthalene. Approximately 0.250 mg/L of naphthalene was found in the suspended solids.

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Analysis of the filtered sample composite used in the study showed slightly lower than expected levels of TOC and phenolics. The naphthalene content was only 0.335 mg/L, below the treatment objective of 0.5 mg/L and 100 times lower than expected. The composition of the filtered water sample is listed below:

TOC	58 mg/L
Phenolics	5.3 mg/L
Naphthalene	0.335 mg/L

An ACT study was conducted simulating a 4 ft. diameter adsorber containing 2000 lbs of F-300 GAC operating at a surface loading rate of 2.80 gpm/ft^2 (35 gpm). These conditions simulated a ~~15~~ minute contact time. The study was continued until near 100% breakthrough of TOC was observed. The results of the study have been compiled in Table I and Figures 1,2,3, and 4.

Because of the early naphthalene breakthrough, we are unable to provide a sufficient volume of contaminate-free ACT effluent to the customer for PNA analysis. Naphthalene breakthrough occurred after 15.9 simulated days of treatment and had reached 0.209 mg/L at the termination of the study.

Samples were collected manually for determination of TOC, phenolics and napthalene. TOC was monitored during the ACT run by analysis on a Beckman TOC analyzer. The study was terminated when TOC levels of the effluents reached 95% of the influent concentration. Naphthalene was determined by gas chromatography using a Tekmar LSC-1 sample concentrator and a flame ionization detector. Samples for the determination of phenolics were submitted to an outside laboratory for analysis by the 4-aminoantipyrine method. This test measures the total phenol, ortho and meta substituted phenols, and those para substituted phenols in which the substitution is a carboxyl, halogen, methoxyl or sulfonic acid group. The samples which were submitted to the outside laboratory for analysis had been screened in our laboratory by liquid chromatography with UV detection. It was noted that the phenol (C_6H_5OH) concentrations of the samples were low in comparison to the total of substituted phenolics noted.

/njt

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TABLE I

KEYSTONE ENVIRONMENTAL/SOUTH CAVALCADE, TX
TSR #0108-28

ACT Effluent Data Table

Simulated Days	Simulated MM Gallons	TOC mg/l	Naphthalene ug/l	Phenolics mg/l	Carbon Use Rate, In Lbs/1000 gallons
0.24	0.0124	5			161.29
1.67	0.0850			<0.04	23.53
2.56	0.1303	3			15.35
3.46	0.1755	6		<0.04	11.40
4.35	0.2207	5			9.06
5.24	0.2659	7		0.08	7.52
6.13	0.3112	6			6.43
7.02	0.3564	6	ND	0.07	5.61
8.80	0.4469	8		<0.04	4.48
10.58	0.5373	14		0.15	3.72
11.47	0.5826		ND		3.43
12.36	0.6278	16		1.90	3.19
14.14	0.7182	28			2.78
15.92	0.8087	33	2	6.60	2.47
17.71	0.8992	44			2.22
19.49	0.9896	47		7.70	2.02
21.27	1.0801	33			1.85
23.05	1.1705	50			1.71
24.83	1.2610	50	26		1.59
26.61	1.3515	50			1.48
33.74	1.7133	52	38		1.17
42.64	2.1656	52	78		0.92
51.55	2.6179	55	122		0.76
59.56	3.0249	55	209		0.66

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Figure 1

KEYSTONE ENVIRONMENTAL / S. CAVALCADE, TX.
TSR# 0188-28
ACT SIMULATED BREAKTHROUGH CURVE
FOR REMOVAL OF PHENOLICS FROM GROUNDWATER

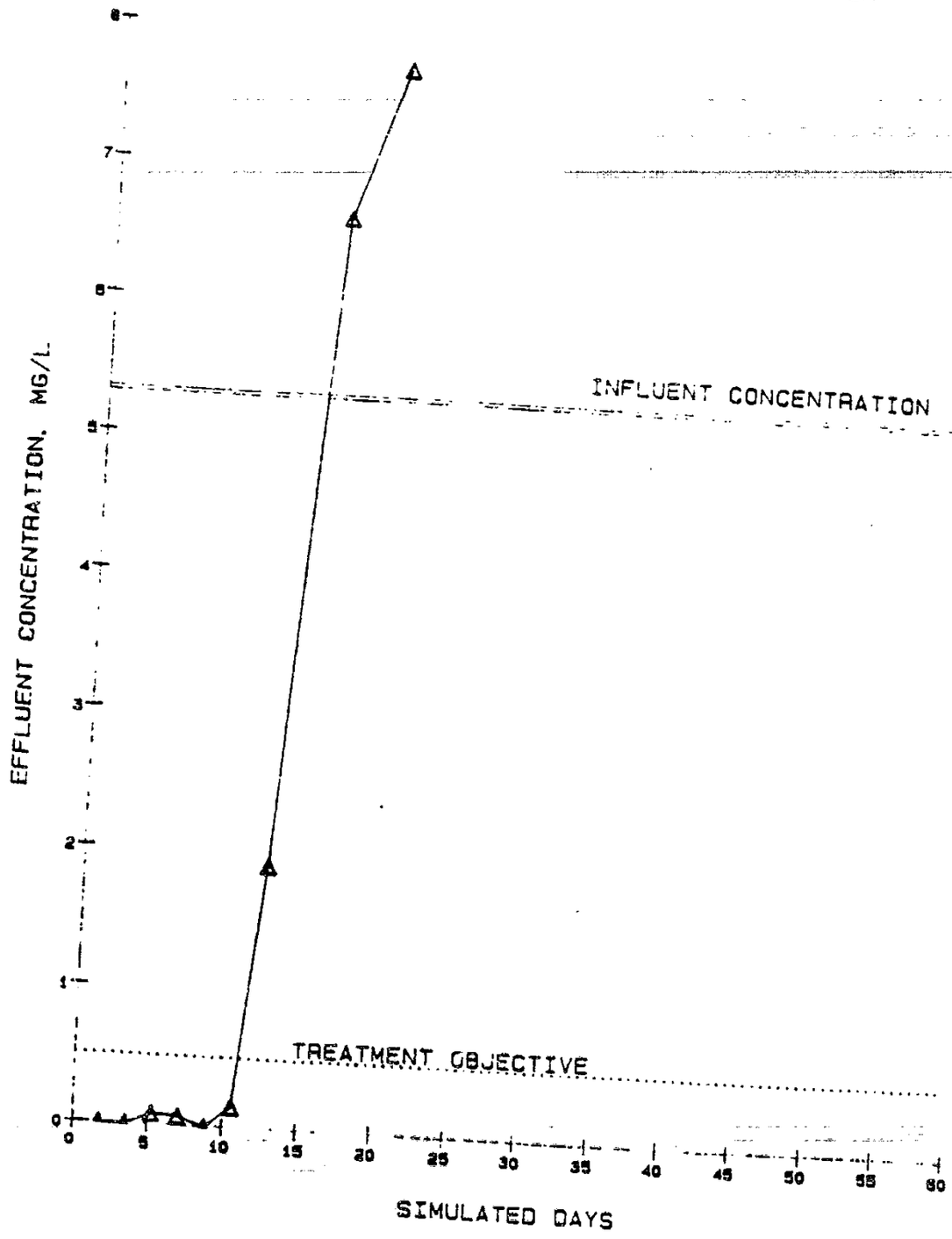

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Figure 2

KEYSTONE ENVIRONMENTAL / S. CAVALCADE, TX.
TSR# 0188-28
ACT SIMULATED BREAKTHROUGH CURVE
FOR REMOVAL OF TOC FROM GROUNDWATER

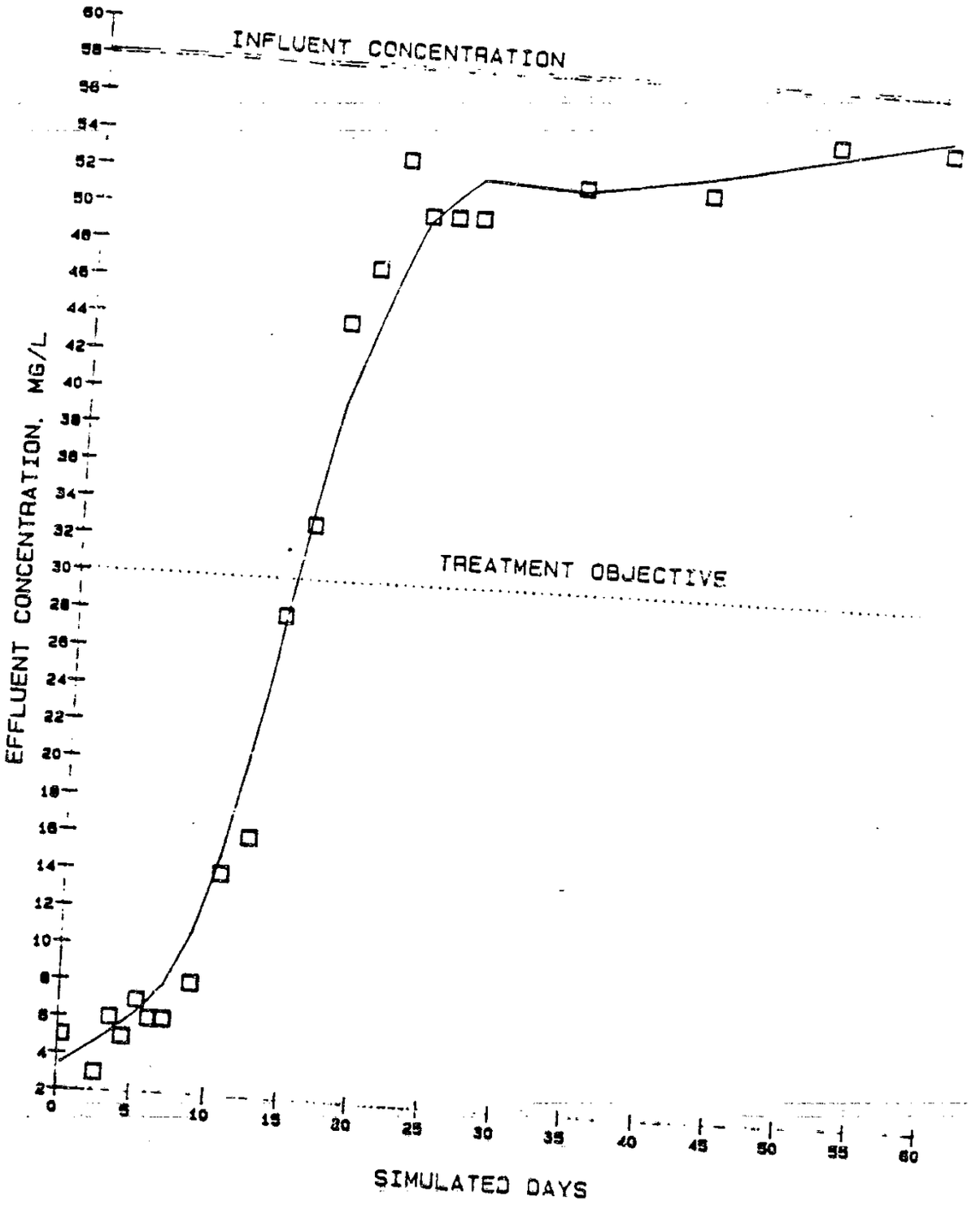

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Figure 3

KEYSTONE ENVIRONMENTAL / S. CAVALCADE, TX.
TSR# 0188-28
ACT SIMULATED BREAKTHROUGH CURVE
FOR REMOVAL OF NAPHTHALENE FROM GROUNDWATER

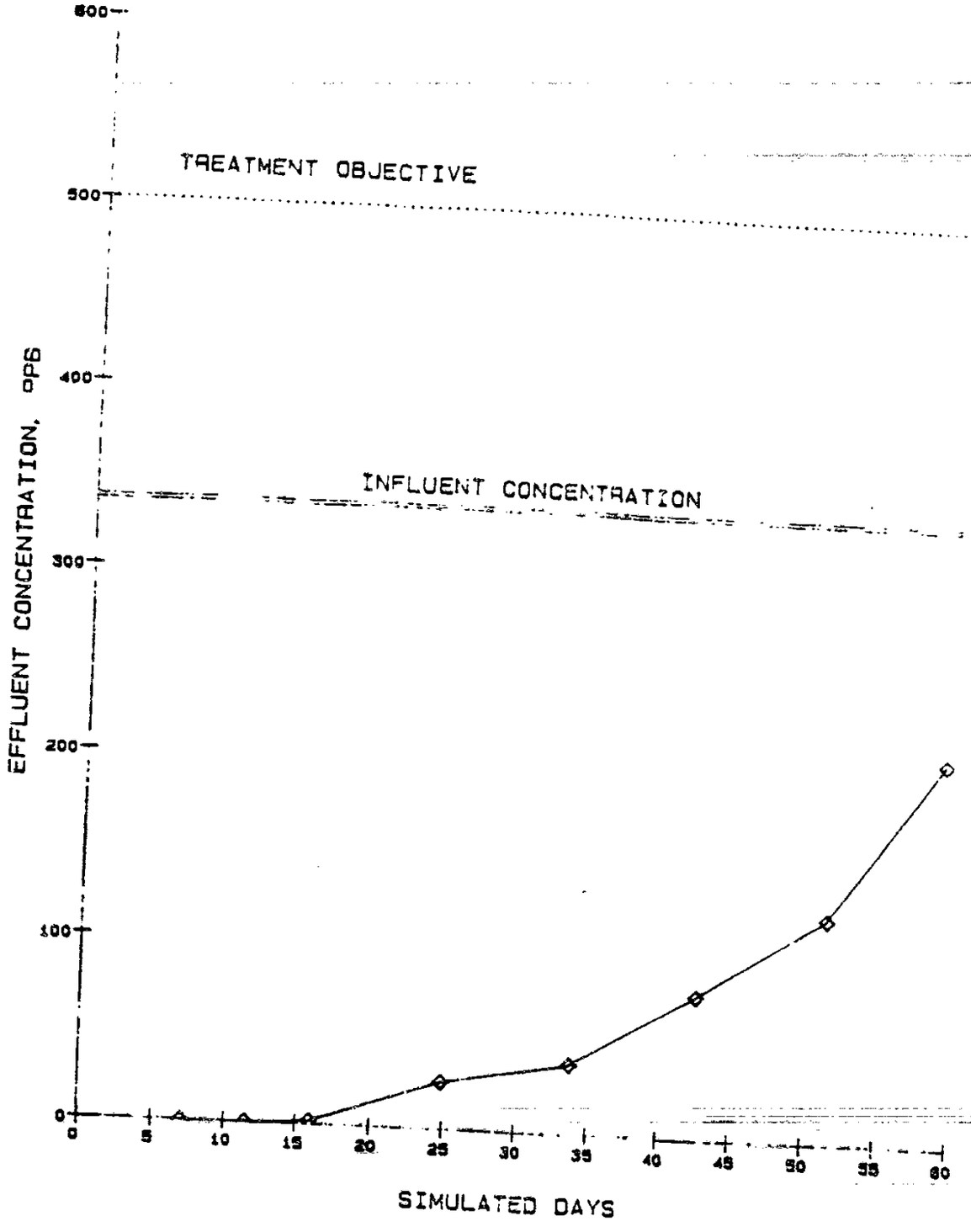

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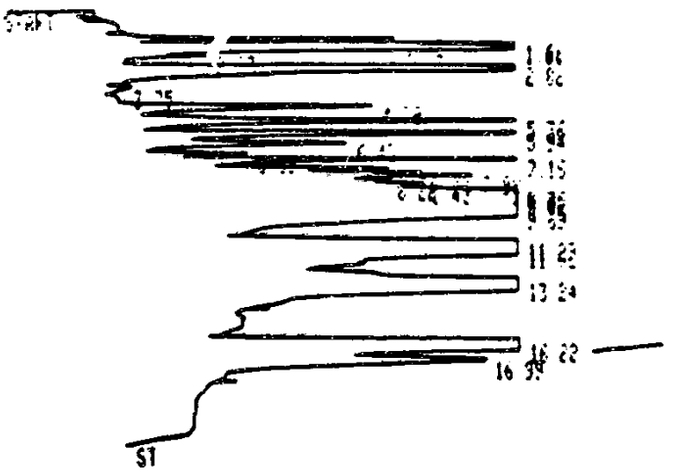
Figure 4

Chromatogram of Volatile Hydrocarbons in Effluent
Sample at 26 ug/L Naphthalene Breakthrough
Level



Peak at R.T. 16.22 Naphthalene

1481 5/84

CALGON CARBON CORPORATION
TECHNICAL SUPPORT REQUEST

ORIGINAL TSR TO: Melissa Kratz ~~LOIS FULLER, 87~~

TSR NUMBER: 0188-28

DATE: 1-18-88

ORIGINATOR & DEPT.: G.H. GUNNERSON.

PURCHASE ORDER COVERING THIS WORK?

☐ NO ➡ FILL IN PROPER PJC NO. _____

☒ YES ➡ P.O. NO. ~~Fx-Income~~ 110-8-30325

P.O. AMT. _____

* CHARGE NO _____

*LEAVE BLANK – WILL BE ASSIGNED BY SALES SERVICE.

CUSTOMER: Keystone Environmental

ADDRESS: Monroeville, PA.

CONTACT: MARK SMOCK

TELEPHONE: 327-2000 X234

PRODUCT: F-300

FINAL REPORT DISTRIBUTION COPIES TO		AFTER TSR APPROVAL ACD COPIES TO	
REG. MGR.	- FPM	REG. MGR.	- FPM
SALESMAN	- RMM	SALESMAN	- RMM
APPLI. ENGR.	- GHG	APPLI. ENGR.	- GHG 10
DIR. OF SALES	- VAS	DIR. OF SALES	- VAS 0
DIR. OF R & D	- RJC	SALES SERV. DEPT.	- MCR 0
MKTG. DIR./MGR.	- MMC	DIR. OF R & D	- RJC 0
		MKTG. DIR./MGR.	- MMC 0

DOES APPLICATION INVOLVE A NEW PRODUCT OR APPLICATION? ☐ YES ☑ NO

IN YES, INDICATE ORIGIN OF CONCEPT. ☐ SELF ☐ CUSTOMER ☐ JOINT ☐ OTHER

MARKETING

SALES: PROTECTED $ _____ /YEAR POTENTIAL _____ /YEAR

REQUESTED COMPLETION DATE ASAP SAMPLES AVAILABLE? 1-19-88

PROBLEM: ACT for CAVALCADE, TEXAS PLANT
TOC - 63 ppm IN – 30 ppm OUT objective 1.
Phenol 8 ppm - IN - 0.5 ppm OUT "
Naphthalene 35 - 0.5 ppm " maximum
ACT - 15 MIN EBCT, pH = 7.2, BOD = 25 ppm, COD-58
Setting is only pretreatment with no polymers.

SAFETY PRECAUTIONS: Samples to be sent back to him please check on -equivalent

RESEARCH

ACTION TO BE TAKEN:

ESTIMATED COST $ _____ R & D ESTIMATED COST $ _____ CAL

APPROVALS

MANAGER | R&D SUPERVISOR

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Date 1-18-87 TSR No. 0188-28

ACCELERATED COLUMN TEST REQUEST

Customer Name Keystone ENVIRONMENTAL

Location MONROEVILLE, PA

Application Engineer GARY GUNNERSON Salesperson FFM

1. Process or System Description (PROVIDE AS MUCH DETAIL AS POSSIBLE-ATTACH PAGES IF NECESSARY):

1. Application Area: Groundwater X Wastewater ____ Process ____
2. Description of the Customer Process or Stream:

① ACT FOR GROUND WATER APPLICATION,
② CLIENT DOES NOT KNOW FLOW RATE YET
③ THE PLANT IS THE CALVACADE TEXAS PLANT.
④ No pretreatment for groundwater other than settling

3. Stream Composition (Detail All Components, Concentrations, etc.):

TOC - IN - 630ppm OUT - 30ppm
Phenol - IN 8 " OUT - 0.5ppm
Naphtalene - IN 35" OUT - 0.5ppm Max

4. Does the Sample Contain Volatiles? yes/no If yes, special sampling procedures should be arranged: Cold, Clear
5. Sample Storage Requirements: Ambient/Refrigerate/Other-

6. Sample Properties: pH 7.2 TOC 63 Conductivity —

Suspended Solids Neglig Color — Other Known Properties ____

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TSR No. 0188-25

ACCELERATED COLUMN TEST REQUEST

II. ACT SIMULATION CONDITIONS:

1. Sample Pre-Treatment Required None

2. Can this ACT be Run to a Specific Minimum Carbon Usage Rate or Days Simulated? yes/no What is Acceptable _____ #/1000 Gallons or _____ Days Simulated?

3. What is the Specific Treatment or Monitoring Objective(s) 30ppm - TOC ; 0.5ppm phenol and 0.5ppm Naphtalene

4. Adsorber Mode Pulse/Fixed Series/Parallel - Up/Down Flow

5. Adsorber Size Model 2 or 10

6. Carbon Type F300 Weight _____

7. Flow Rate — GPM or — GPM/FT^2

8. Empty Bed Contact Time (EBCT) 15 Minutes

9. Temperature 55

10. pH 7.2

11. Special Sampling, Monitoring or Simulation Requirements

Please talk to Mark Smock for details of special samples need to be taken.

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CALGON CARBON CORPORATION
P.O. BOX 717 • PITTSBURGH, PA 15230-0717

CALGON REACTIVATED CARBON
TYPICAL PROPERTIES

TEST	PROPERTY*
IODINE NUMBER	750**
ASH, WT. %	9
A.D., G/CC	.60
MESH SIZE NOMENCLATURE	8 X 40
PARTICLE SIZE	
THRU U.S. #40 MESH, %	5

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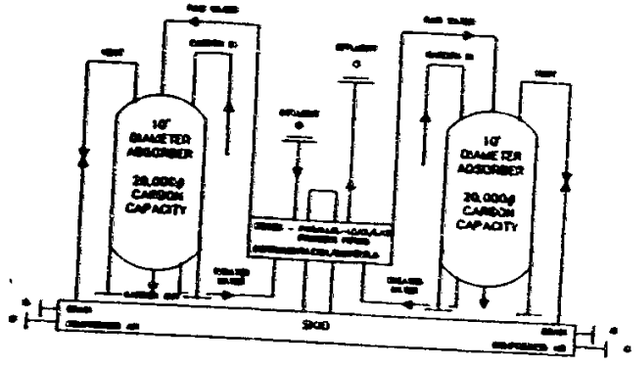
* PROPERTIES REPRESENT TYPICAL RESULTS BASED ON (PRE-QUENCHED) DRY FURNACE DISCHARGE.

** TO PERFORM THE IODINE NUMBER TEST ON REPRESENTATIVE WET CARBON SAMPLES, THE SAMPLES MUST BE DRIED UNDER A NITROGEN PURGE, VACUUM OR OTHER CONDITIONS WHICH ELIMINATE OXYGEN. IN ADDITION, THE REPRESENTATIVE SAMPLES MUST BE PULVERIZED TO 95% < 325 MESH TO ACHIEVE THE REQUIRED KINETICS OF THE ANALYTICAL TEST.

STOCK
125# NON BACKWASH SYSTEM

MODEL 10

	125 NBW
TANK SHIPPING WEIGHT, #	15,700
SKID SHIPPING WEIGHT, #	2,700
PIPE SHIPPING WEIGHT, #	6,000
TANK WEIGHT (FULL OF WATER), #	81,000
TANK OPERATING WEIGHT, #	99,000
UNIT SHIPPING WEIGHT, # (ASSEMBLED DRY WEIGHT)	41,100
UNIT WEIGHT (FULL OF WATER), #	173,300
UNIT OPERATING WEIGHT, #	194,300
HEAVIEST SINGLE PIECE, #	15,700



	STOCK DESIGN
VESSELS (2)	10' DIA
ASME STAMP	YES
HYDRO	FULL
PRESSURE	125#
LINING	RUBBER
MANWAYS	1-16"x18" 1- 20" DIA.
PIPING	
SYSTEM TYPE	LEAD/LAG
PROCESS SIZE	6"
PROCESS PIPING MTRL	C.S.
CARBON TRANSFER PIPE	
CARBON PIPE SIZE	4"
CARBON PIPE MTRL	C.S. & CS/PVC LINED
INSTRUMENTATION	LOCAL PRESSURE GAGE PRESSURE DIFFERENTIAL SWITCHES
INSTALLATION	INSTALLATION BY CALGON CARBON
PAINTING	FINISH PAINT

*CUSTOMER TIE IN POINTS ABOVE BASE

INFLUENT -	6 FT
EFFLUENT -	16 FT
AIR -	4 IN
DRAIN -	6 IN

MODEL 10 DIMENSIONS

BASE	- 24'x8'
MAX LG	- 26'-8"
MAX WIDTH	- 10'-6"
MAX HT	- 19'-6"
CLEARANCE HT LINE	- 21'-0"

CALGON
CALGON CARBON CORPORATION

STOCK
125#
NON BACKWASH

STOCK DESIGN MODEL 10
125# NON BACKWSH
ADSORPTION SYSTEM

90-88-1657

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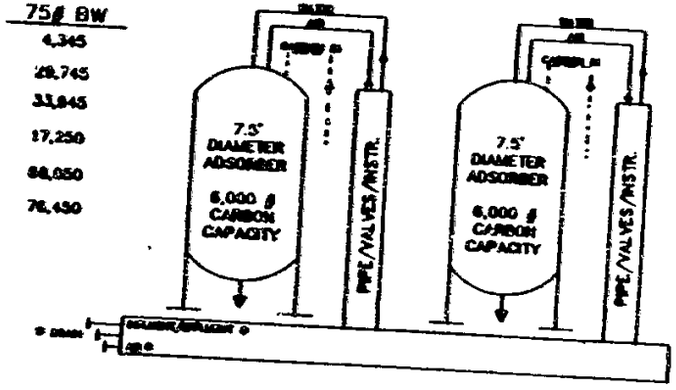
STOCK
75# BACKWASH SYSTEM

MODEL 7.5

	75# BW
TANK WEIGHT, # EACH	4,345
TANK WEIGHT (FULL OF WATER), # EACH	29,745
TANK OPERATING WEIGHT, # EACH	33,845
UNIT SHIPPING WEIGHT, # (ASSEMBLED DRY WEIGHT)	17,250
UNIT WEIGHT (FULL OF WATER), #	68,050
UNIT OPERATING WEIGHT, #	76,450



STOCK DESIGN FEATURES	
VESSELS (2)	7.5' DIA.
ASME STAMP	YES
VACUUM	PARTIAL
PRESSURE	75#
LINING	7168HAR
MANWAYS	1-16" X 16"
	1-20" DIA
PIPING	
SYSTEM TYPE	LEAD/LAG
PROCESS SIZE	4"
PROCESS PIPING MTRL.	C.S.
BW PIPING	6"
CARBON TRANSFER SYS.	
CARBON PIPE SIZE	2"
CARBON PIPE MTRL.	C.S. & CS/PVC LINED
INSTRUMENTATION	LOCAL PRESSURE
INSTALLATION	ONE LIFT BY CRANE
PAINTING	FINISH PAINT
UNDERDRAIN	PVC LATERAL

*CUSTOMER TIE IN POINT ABOVE BASE:

INFLUENT –	4 1/2" in.
EFFLUENT –	4 1/2" in.
AIR –	3 1/4" in.
DRAIN –	4" in.

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MODEL 7.5 DIMENSIONS

BASE	– 23'–3"x8'–0"
MAX LG	– 23'–3"
MAX WIDTH	– 8'–0"
MAX HT	– 9'–7"
CLEARANCE HT LINE	– 10'–7"

NOTE: SYSTEM IS A UNITIZED ASSEMBLY AND MAY BE SHIPPED FROM CALGON CARBON CORPORATION WITH CARBON PRE-LOADED.

CALGON
CALGON CARBON CORPORATION

STOCK
75#
BACKWASH

PLANT

TITLE
STOCK DESIGN MODEL 7.5
75# BACKWASH
ADSORPTION SYSTEM

DRAWN WE

CALGON CARBON CORPORATION
MOBILE-PAC ADSORPTION SERVICE

Calgon Carbon Corporation's Mobile-Pac Adsorption Service is provided to offer users of small amounts of granular activated carbon the convenience of both having an easy-to-use adsorber and the capability to return the spent carbon for safe disposition.

THE MOBILE-PAC ADSORBER

The Adsorber is a non-pressure tank, constructed of type 316 stainless steel and EPR gaskets. The Adsorber is designed to contain 2,000 lbs. of a selected grade of Calgon Carbon's granular activated carbon (GAC).

The Adsorber, weighing 7,500 lbs. in operation, can be transported via for lift and set on a level area for operation. Kamlock hose connections (2") are used to connect influent and effluent supply. The untreated water enters the top of the unit, flows down through the GAC collected by a screened outlet and exits the coned section. Sample taps are provided on the influent and effluent. The system pressure drop is shown on the curve below. The proper flow is determined by the desired contact time (30 gpm = 15 minutes contact time). Mobile-Pac units can be arranged in parallel or series, if desired.

The Adsorbers are not to be operated above 15 psig, and a rupture disk is included to assure that this pressure is not exceeded.

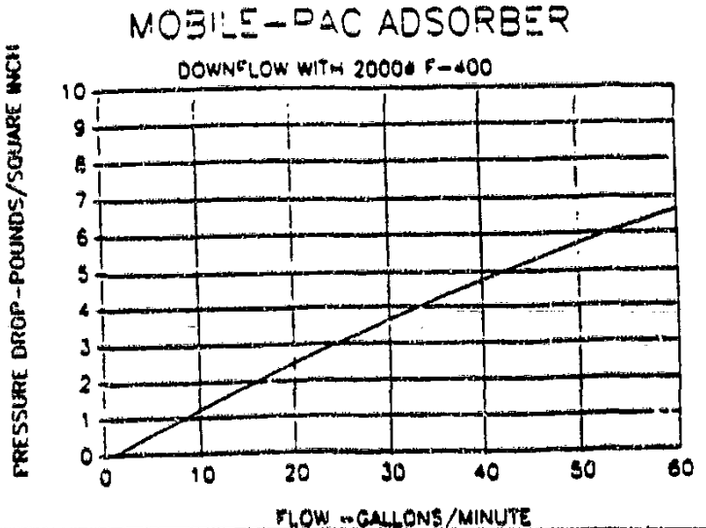
THE ADSORPTION SERVICE

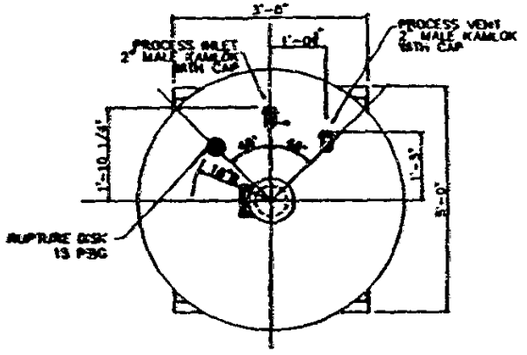
The user of the adsorption service has the convenience of using the Mobile-Pac Adsorber for eatment, and then using the unit as a shipment container to return the spent carbon to Calgon Carbon.

If the spent GAC has been tested and approved by Calgon Carbon, the Mobile-Pac can be returned to Calgon Carbon. Upon return, the spent GAC will be removed by Calgon Carbon and thermally regenerated before any further disposition. If additional treatment is still required, the spent Mobile-Pac can be replaced with a fresh Mobile-Pac, with the simple hose connections utilized to switch units. The spent Mobile-Pac is drained of free water and returned to Calgon Carbon.

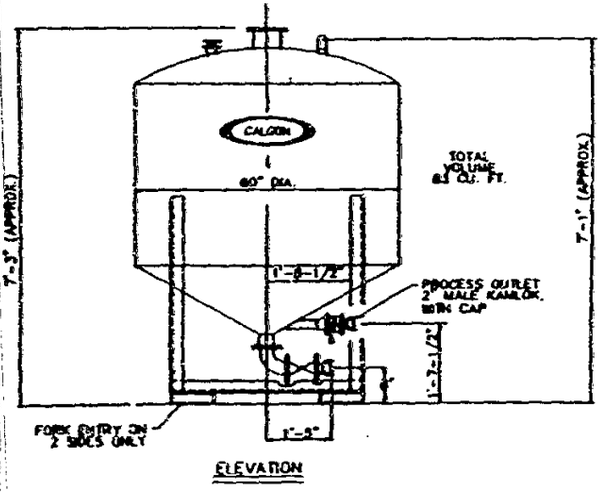
ADDITIONAL INFORMATION

Contact your Calgon Carbon Technical Sales Representative for more information on the Mobile-Pac Adsorption Service.





PLAN



ELEVATION

MATERIALS:

ALL PROCESS CONTACT MATERIALS ARE 316 STAINLESS STEEL WITH EPR GASKETS AND SEALS.

OTHER PARTS ARE 304 STAINLESS STEEL.

CAPACITY:

CONTAINS 2000 lbs (DRY BASIS) GRANULAR ACTIVATED CARBON MAY PROCESS 60 gpm WITH A 6 psig PRESSURE DROP.

PRESSURE RATING:

DO NOT EXCEED 15 psig.
RUPTURE DISK PROTECTED.
DO NOT EXCEED 200F
DO NOT USE FOR VACUUM SERVICE

WEIGHTS:

EMPTY	1035 #
FILLED DRY	3035 #
FILLED WET & DRAINED	5035 #
OPERATING	7400 #
MAX RETURN SHIPPING	5600 #

CONNECTIONS:

INLET	2" QUICK CONNECT
VENT	2" QUICK CONNECT
TREATED WATER	2" QUICK CONNECT
INLET SAMPLE	1/2" FNPT
TREATED WATER SAMPLE	1/2" FNPT

PROJECT	CALGON CARBON CORPORATION P.O. BOX 717 PITTSBURGH PA 15230-0717	PLANT
SCALE 1/2" = 1'-0"		TITLE MOBILE – PAC ADSORBER GENERAL ARRANGEMENT
DRAWN ME		
DATE 2-3-88		DWG NO 90-88-1667
CHK'D JDH		REV 1
APPRV'D		

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APPENDIX 10

SOIL WASHING SCREENING RUN RESULTS
AREA A-04 SOIL SAMPLES
SURFACE SAMPLE (T0018A) AND SUBSURFACE SAMPLE (T0018B)

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KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1 SUMMARY OF ANALYTICAL DATA PRODUCED ON 01/21/88 AT 16:37 PAGE

SAMPLE #	RSLT. LNE			SOURCE
% MOISTURE				
88010117	% Solids @103 C.	:	81.0	T0018/A #1
88010118	% Solids @103 C.	:	81.6	T0018/A #3
88010119	% Solids @103 C.	:	82.5	T0018/A #4
88010120	% Solids @103 C.	:	86.8	T0018/A RAW
88010121	% Solids @103 C.	:	80.8	T0018/B #1
88010122	% Solids @103 C.	:	81.2	T0018/B #2
88010123	% Solids @103 C.	:	81.2	T0018/B #5
88010124	% Solids @103 C.	:	86.8	T0018/B RAW
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC				
88010117	Oil & Grease, mg/Kg.	:	1050	T0018/A #1
88010118	Oil & Grease, mg/Kg.	:	967	T0018/A #3
88010119	Oil & Grease, mg/Kg.	:	1073	T0018/A #4
88010120	Oil & Grease, mg/Kg.	:	48300	T0018/A RAW
88010121	Oil & Grease, mg/Kg.	:	<50.0	T0018/B #1
88010122	Oil & Grease, mg/Kg.	:	<50.0	T0018/B #2
88010123	Oil & Grease, mg/Kg.	:	100	T0018/B #5
88010124	Oil & Grease, mg/Kg.	:	8010	T0018/B RAW
METHYLENE CHLORIDE EXTRACTABLES				
88010117	MeCl Extractables, mg/Kg	:	2690	T0018/A #1
88010118	MeCl Extractables, mg/Kg	:	2370	T0018/A #3
88010119	MeCl Extractables, mg/Kg	:	2270	T0018/A #4
88010120	MeCl Extractables, mg/Kg	:	70900	T0018/A RAW
88010121	MeCl Extractables, mg/Kg	:	130	T0018/B #1
88010122	MeCl Extractables, mg/Kg	:	190	T0018/B #2
88010123	MeCl Extractables, mg/Kg	:	210	T0018/B #5
88010124	MeCl Extractables, mg/Kg	:	13100	T0018/B RAW

The above results are on an as received basis.

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KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 01/21/88 AT 16:35 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88010117	T0018/A #1	TREATABILITY STUDY	01/11/88	01/11/88	M8801040
88010118	T0018/A #3	TREATABILITY STUDY	01/11/88	01/11/88	M8801040
88010119	T0018/A #4	TREATABILITY STUDY	01/11/88	01/11/88	M8801040
88010120	T0018/A RAW	TREATABILITY STUDY	01/11/88	01/11/88	M8801040
88010121	T0018/B #1	TREATABILITY STUDY	01/11/88	01/11/88	M8801040
88010122	T0018/B #2	TREATABILITY STUDY	01/11/88	01/11/88	M8801040
88010123	T0018/B #5	TREATABILITY STUDY	01/11/88	01/11/88	M8801040
88010124	T0018/B RAW	TREATABILITY STUDY	01/11/88	01/11/88	M8801040

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APPENDIX 11

SOIL WASHING FINAL RUN RESULTS
AREA A-04 SOIL SAMPLES
SURFACE SAMPLE (T0018A) AND SUBSURFACE SAMPLE (T0018B)

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 02/23/88 AT 16:53 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
% MOISTURE			
8020187	% Solids @103 C.....	: 86.6	T0018/A-RAW-F
8020188	% Solids @103 C.....	: 83.0	T0018/A-CL-F
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
8020187	Oil & Grease, mg/Kg.....	: 50000	T0018/A-RAW-F
8020188	Oil & Grease, mg/Kg.....	: 1090	T0018/A-CL-F
METHYLENE CHLORIDE EXTRACTABLES			
8020187	MeCl Extractables, mg/Kg	: 70100	T0018/A-RAW-F
8020188	MeCl Extractables, mg/Kg	: 1810	T0018/A-CL-F

The above results are on an as received basis.

008069

008069

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020187

Source: TOO18/A-RAW-F
Description: TREATABILITY STUDY

Date Collected: 02/03/88
Date Received: 02/05/88

Date Extracted: 02/09/88
Date Analyzed: 02/17/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

Polynuclear Aromatic Hydrocarbons

Acenaphthene	670000
Acenaphthylene	INTERFERENCE
Anthracene	18400
Benzo(a)anthracene	16200
Benzo(a)pyrene	12000
Benzo(b)fluoranthene	22900
Benzo(g,h,i)perylene	18000
Benzo(k)fluoranthene	6780
Chrysene	18500
Dibenz(ah)anthracene	36600
Fluoranthene	49300
Fluorene	36700
Indeno(123-cd)pyrene	17000
Phenanthrene	37700
Pyrene	INTERFERENCE

Other Polynuclear Aromatic Compounds tested:

Carbazole	8400
Naphthalene	INTERFERENCE

The above results are reported in ug/Kg.

All PAH identifications are from retention data only.

008070

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020188

Source: T0018/A-CL-F
Description: TREATABILITY STUDY

Date Collected: 02/03/88
Date Received: 02/05/88

Date Extracted: 02/09/88
Date Analyzed: 02/18/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008071

Polynuclear Aromatic Hydrocarbons

Acenaphthene	100000
Acenaphthylene	14600
Anthracene	58500
Benzo(a)anthracene	36400
Benzo(a)pyrene	8740
Benzo(b)fluoranthene	13900
Benzo(g,h,i)perylene	5980
Benzo(k)fluoranthene	6080
Chrysene	42100
Dibenz(ah)anthracene	6590
Fluoranthene	122000
Fluorene	68300
Indeno(123-cd)pyrene	4820
Phenanthrene	219000
Pyrene	91300

Other Polynuclear Aromatic Compounds tested:

Carbazole	<1000
Naphthalene	127000

The above results are reported in ug/Kg.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 02/24/88 AT 14:51 PAGE

SAMPLE #	RSLT LNE		SOURCE
% MOISTURE			
88020276	% Solids @103 C..... :	86.4	T0018/B/RAW-F
88020277	% Solids @103 C..... :	78.4	T0018/B/CL-F
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
88020276	Oil & Grease, mg/Kg..... :	5570	T0018/B/RAW-F
88020277	Oil & Grease, mg/Kg..... :	53.3	T0018/B/CL-F
METHYLENE CHLORIDE EXTRACTABLES			
88020276	MeCl Extractables, mg/Kg :	7180	T0018/B/RAW-F
88020277	MeCl Extractables, mg/Kg :	<50.0	T0018/B/CL-F

The above results are on an as received basis.

008072

008072

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020276

Source: T0018/B/RAW-F
Description: TREATABILITY STUDY

Date Collected: 02/09/88
Date Received: 02/09/88

Date Extracted: 02/10/88
Date Analyzed: 02/19/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008073

Polynuclear Aromatic Hydrocarbons

Acenaphthene	757000
Acenaphthylene	142000
Anthracene	260000
Benzo(a)anthracene	212000
Benzo(a)pyrene	69300
Benzo(b)fluoranthene	93000
Benzo(g,h,i)perylene	67400
Benzo(k)fluoranthene	37100
Chrysene	206000
Dibenz(ah)anthracene	102000
Fluoranthene	632000
Fluorene	487000
Indeno(123-cd)pyrene	38700
Phenanthrene	1470000
Pyrene	567000

Other Polynuclear Aromatic Compounds tested:

Carbazole	8040
Naphthalene	1630000

The above results are reported in ug/Kg.

The above results are on an as received basis.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample 88020277

Source: T0018/B/CL-F
Description: TREATABILITY STUDY

Date Collected: 02/09/88
Date Received: 02/09/88

Date Extracted: 02/10/88
Date Analyzed: 02/20/88

Clean up Method

silica gel clean-up ✓ yes ___ no
florisil clean-up ___ yes ___ no
alumina clean-up ___ yes ___ no
sulfur clean-up ___ yes ___ no

008074

Polynuclear Aromatic Hydrocarbons

Acenaphthene	:	1580
Acenaphthylene	:	212
Anthracene	:	722
Benzo(a)anthracene	:	791
Benzo(a)pyrene	:	222
Benzo(b)fluoranthene	:	559
Benzo(g,h,i)perylene	:	247
Benzo(k)fluoranthene	:	153
Chrysene	:	764
Dibenz(ah)anthracene	:	341
Fluoranthene	:	2470
Fluorene	:	1070
Indeno(123-cd)pyrene	:	170
Phenanthrene	:	5270
Pyrene	:	1980

Other Polynuclear Aromatic Compounds tested:

Carbazole	:	67.9
Naphthalene	:	1870

The above results are reported in ug/Kg.

The above results are on an as received basis.

All PAH identifications are from retention data only.

APPENDIX 12

IN SITU SOIL BIORECLAMATION
SOIL COLUMN STUDY RESULTS

APPENDIX 12

SOIL COLUMN INFLUENT GROUNDWATER RESULTS

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 01/28/88 AT 11:52 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88010127	COL. INF	TREATABILITY STUDY	01/11/88	01/11/88	M8801042

008077

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 01/28/88 AT 11:53 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
BIOCHEMICAL OXYGEN DEMAND (5 DAY, TOTAL)			
88010127	BOD, mg/L.....	: 42.0	COL. INF
CHEMICAL OXYGEN DEMAND (TOTAL)			
88010127	COD (Total), mg/L...	: 240	COL. INF
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
88010127	Oil & Grease, mg/L..	: 20.8	COL. INF
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88010127	Phenol, mg/L.....	: 5.70	COL. INF
TOTAL KJELDAHL NITROGEN			
88010127	TKN as N, mg/L.....	: 8.80	COL. INF
TOTAL ORGANIC CARBON			
88010127	TOC, mg/L.....	: 56.7	COL. INF
TOTAL PHOSPHATE			
88010127	Total PO4, mg/L.....	: 6.95	COL. INF
pH			
88010127	pH, units.....	: 7.5	COL. INF

008078

008078

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 2: SUMMARY OF METALS DATA — PRODUCED ON 01/28/88 AT 11:54 — PAGE

SAMPLE #	RSLT. LNE		SOURCE	
ANTIMONY				
88010127	Antimony, ug/L..... :	<60.0	COL.	INF
ARSENIC				
88010127	Arsenic, ug/L..... :	12.7	COL.	INF
BERYLLIUM				
88010127	Beryllium, ug/L..... :	<5.00	COL.	INF
CADMIUM				
88010127	Cadmium, ug/L..... :	<5.00	COL.	INF
CHROMIUM				
88010127	Chromium, ug/L..... :	<10.0	COL.	INF
COPPER				
88010127	Copper, ug/L..... :	<25.0	COL.	INF
LEAD				
88010127	Lead, ug/L..... :	<5.00	COL.	INF
MERCURY				
88010127	Mercury, ug/L..... :	<0.200	COL.	INF
NICKEL				
88010127	Nickel, ug/L..... :	<40.0	COL.	INF
SELENIUM				
88010127	Selenium, ug/L..... :	<5.00	COL.	INF
SILVER				
88010127	Silver, ug/L..... :	<10.0	COL.	INF
THALLIUM				
88010127	Thallium, ug/L..... :	<10.0	COL.	INF
ZINC				
88010127	Zinc, ug/L..... :	<20.0	COL.	INF

008079

008079

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 3: SUMMARY OF PAH DATA

Sample: 88010127

Source: COL. INF
Description: TREATABILITY STUDY

Date Collected: 01/11/88
Date Received: 01/11/88

Date Extracted: 01/12/88
Date Analyzed: 01/14/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008080

Polynuclear Aromatic Hydrocarbons

Acenaphthene	:	352
Acenaphthylene	:	178
Anthracene	:	30.5
Benzo(a)anthracene	:	13.1
Benzo(a)pyrene	:	1.68
Benzo(b)fluoranthene	:	2.90
Benzo(g,h,i)perylene	:	1.62
Benzo(k)fluoranthene	:	1.03
Chrysene	:	10.8
Dibenz(ah)anthracene	:	1.65
Fluoranthene	:	83.5
Fluorene	:	189
Indeno(123-cd)pyrene	:	0.766
Phenanthrene	:	288
Pyrene	:	83.8

Other Polynuclear Aromatic Compounds tested:

Carbazole	:	304
Naphthalene	:	2700

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 03/29/88 AT 11:03 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88030074	COL. INF(FINAL)	TREATABILITY STUDY	03/03/88	03/03/88	M8803016

008081

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 03/29/88 AT 11:04 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
BIOCHEMICAL OXYGEN DEMAND (5 DAY, TOTAL)			
88030074	BOD, mg/L.....	: 240	COL. INF(FINAL)
CHEMICAL OXYGEN DEMAND (TOTAL)			
88030074	COD (Total), mg/L...	: 178	COL. INF(FINAL)
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
88030074	Oil & Grease, mg/L..	: 26.3	COL. INF(FINAL)
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88030074	Phenol, mg/L.....	: 3.47	COL. INF(FINAL)
TOTAL KJELDAHL NITROGEN			
88030074	TKN as N, mg/L.....	: 7.35	COL. INF(FINAL)
TOTAL ORGANIC CARBON			
88030074	TOC, mg/L.....	: 52.6	COL. INF(FINAL)
TOTAL PHOSPHATE			
88030074	Total PO4, mg/L.....	: 6.10	COL. INF(FINAL)
pH			
88030074	pH, units.....	: 7.6	COL. INF(FINAL)

008082

008082

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 2: SUMMARY OF METALS DATA — PRODUCED ON 03/29/88 AT 11 04 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
ANTIMONY			
38030074	Antimony, ug/L..... :	<60.0	COL. INF(FINAL)
BERYLLIUM			
38030074	Beryllium, ug/L..... :	<5.00	COL. INF(FINAL)
CADMIUM			
38030074	Cadmium, ug/L..... :	<5.00	COL. INF(FINAL)
CHROMIUM			
88030074	Chromium, ug/L..... :	<10.0	COL. INF(FINAL)
COPPER			
38030074	Copper, ug/L..... :	<25.0	COL. INF(FINAL)
LEAD			
38030074	Lead, ug/L..... :	<5.00	COL. INF(FINAL)
MERCURY			
38030074	Mercury, ug/L..... :	<0.200	COL. INF(FINAL)
NICKEL			
38030074	Nickel, ug/L..... :	<40.0	COL. INF(FINAL)
SELENIUM			
88030074	Selenium, ug/L..... :	<5.00	COL. INF(FINAL)
SILVER			
38030074	Silver, ug/L..... :	<10.0	COL. INF(FINAL)
THALLIUM			
38030074	Thallium, ug/L..... :	<10.0	COL. INF(FINAL)
ZINC			
38030074	Zinc, ug/L..... :	<20.0	COL. INF(FINAL)

008083

008083

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 3: SUMMARY OF PAH DATA

Sample: 88030074

Source: COL. INF(FINAL)
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/09/88
Date Analyzed: 03/19/88

Clean up Method

silica gel clean-up ___yes ___no
florisil clean-up ___yes ___no
alumina clean-up ___yes ___no
sulfur clean-up ___yes ___no

008084

Polynuclear Aromatic Hydrocarbons

Acenaphthene	:	146
Acenaphthylene	:	87.8
Anthracene	:	8.97
Benzo(a)anthracene	:	4.60
Benzo(a)pyrene	:	0.841
Benzo(b)fluoranthene	:	1.32
Benzo(g,h,i)perylene	:	0.630
Benzo(k)fluoranthene	:	0.483
Chrysene	:	3.54
Dibenz(ah)anthracene	:	1.10
Fluoranthene	:	25.3
Fluorene	:	35.9
Indeno(123-cd)pyrene	:	0.355
Phenanthrene	:	76.9
Pyrene	:	20.6

Other Polynuclear Aromatic Compounds tested:

Carbazole	:	28.1
Naphthalene	:	739

The above results are reported in ug/L .

All PAH identifications are from retention data only.

APPENDIX 12

SOIL COLUMN EFFLUENT WATER RESULTS

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 02/02/88 AT 08:29 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88010359	AERO COL 3 EFF	TREATABILITY STUDY	01/21/88	01/21/88	M8801100
88010360	ANAERO COL 2 EF	TREATABILITY STUDY	01/21/88	01/21/88	M8801100
88010361	CONT COL 1 EFF	TREATABILITY STUDY	01/21/88	01/21/88	M8801100

008086

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 02/02/88 AT 08:30 — PAGE

SAMPLE #	RSLT LNE		SOURCE
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88010359	Phenol, mg/L.....	2.32	AERO COL 3 EFF
88010360	Phenol, mg/L.....	2.12	ANAERO COL 2 EF
88010361	Phenol, mg/L.....	3.54	CONT COL 1 EFF
TOTAL ORGANIC CARBON			
88010359	TOC, mg/L.....	55.2	AERO COL 3 EFF
88010360	TOC, mg/L.....	64.4	ANAERO COL 2 EF
88010361	TOC, mg/L.....	53.1	CONT COL 1 EFF
TOTAL PHOSPHATE			
88010359	Total PO4, mg/L.....	1.69	AERO COL 3 EFF
88010360	Total PO4, mg/L.....	0.550	ANAERO COL 2 EF
88010361	Total PO4, mg/L.....	<0.100	CONT COL 1 EFF
ORTHOPHOSPHATE			
88010359	Phosphate(o)asP, mg/L	1.37	AERO COL 3 EFF
88010360	Phosphate(o)asP, mg/L	0.390	ANAERO COL 2 EF
88010361	Phosphate(o)asP, mg/L	<0.100	CONT COL 1 EFF

008087

008087

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88010359

Source: AERO COL 3 EFF
Description: TREATABILITY STUDY

Date Collected: 01/21/88
Date Received: 01/21/88

Date Extracted: 01/25/88
Date Analyzed: 01/27/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008088

Polynuclear Aromatic Hydrocarbons

Acenaphthene	65.1
Acenaphthylene	6.87
Anthracene	15.8
Benzo(a)anthracene	8 30
Benzo(a)pyrene	3.97
Benzo(b)fluoranthene	6.18
Benzo(g,h,i)perylene	4.35
Benzo(k)fluoranthene	2.28
Chrysene	6.42
Dibenz(ah)anthracene	6.10
Fluoranthene	51.3
Fluorene	42.6
Indeno(123-cd)pyrene	2.84
Phenanthrene	93.9
Pyrene	44.0

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	3.13

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88010360

Source: ANAERO COL 2 EF
Description: TREATABILITY STUDY

Date Collected: 01/21/88
Date Received: 01/21/88

Date Extracted: 01/25/88
Date Analyzed: 01/27/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008089

Polynuclear Aromatic Hydrocarbons

Acenaphthene	44.0
Acenaphthylene	20.0
Anthracene	3.91
Benzo(a)anthracene	0.653
Benzo(a)pyrene	0.116
Benzo(b)fluoranthene	0.188
Benzo(g,h,i)perylene	<0.050
Benzo(k)fluoranthene	0.069
Chrysene	0.545
Dibenz(ah)anthracene	<0.030
Fluoranthene	7.24
Fluorene	22.1
Indeno(123-cd)pyrene	<0.050
Phenanthrene	32.4
Pyrene	4.76

Other Polynuclear Aromatic Compounds tested:

Carbazole	21.4
Naphthalene	24.0

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88010361

Source: CONT COL 1 EFF
Description: TREATABILITY STUDY

Date Collected: 01/21/88
Date Received: 01/21/88

Date Extracted: 01/25/88
Date Analyzed: 01/27/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008090

Polynuclear Aromatic Hydrocarbons

Acenaphthene	40.5
Acenaphthylene	31.3
Anthracene	2.68
Benzo(a)anthracene	0.401
Benzo(a)pyrene	0.087
Benzo(b)fluoranthene	0.096
Benzo(g,h,i)perylene	<0.050
Benzo(k)fluoranthene	0.049
Chrysene	0.319
Dibenz(ah)anthracene	<0.030
Fluoranthene	4.31
Fluorene	17.5
Indeno(123-cd)pyrene	<0.050
Phenanthrene	22.6
Pyrene	3.10

Other Polynuclear Aromatic Compounds tested:

Carbazole	10.7
Naphthalene	742

The above results are reported in ug/L.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 02/19/88 AT 11:49 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88020086	ANAER. COL. 2 EFF	TREATABILITY STUDY	02/04/88	02/04/88	M8802015
88020087	AERO. COL 3 EFF	TREATABILITY STUDY	02/04/88	02/04/88	M8802015
88020088	CONT. COL. 1 EFF	TREATABILITY STUDY	02/04/88	02/04/88	M8802015

008091

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 02/19/88 AT 11:50 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
TOTAL RECOVERABLE PHENOLICS (As Phenol)			
88020086	Phenol, mg/L	1.86	ANAER. COL. 2 EFF
88020087	Phenol, mg/L	2.17	AERO. COL. 3 EFF
88020088	Phenol, mg/L	0.439	CONT. COL. 1 EFF
ORTHO PHOSPHATE			
88020086	Phosphate(o)asP, mg/L	1.74	ANAER. COL. 2 EFF
88020087	Phosphate(o)asP, mg/L	0.910	AERO. COL. 3 EFF
88020088	Phosphate(o)asP, mg/L	<0.100	CONT. COL. 1 EFF
TOTAL ORGANIC CARBON			
88020086	TOC, mg/L	36.4	ANAER. COL. 2 EFF
88020087	TOC, mg/L	47.2	AERO. COL. 3 EFF
88020088	TOC, mg/L	13.5	CONT. COL. 1 EFF
pH			
88020086	pH, units	7.3	ANAER. COL. 2 EFF
88020087	pH, units	6.9	AERO. COL. 3 EFF
88020088	pH, units	6.8	CONT. COL. 1 EFF

008092

SPECTRIX MONROEVILLE

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020086

Source: ANAER. COL. 2 EFF
Description: TREATABILITY STUDY

Date Collected: 02/04/88
Date Received: 02/04/88

Date Extracted: 02/05/88
Date Analyzed: 02/15/88

Clean up Method

silica gel clean-up:	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008093

Polynuclear Aromatic Hydrocarbons

Acenaphthene	56.3
Acenaphthylene	INTERFERENCE
Anthracene	4.22
Benzo(a)anthracene	0.853
Benzo(a)pyrene	0.092
Benzo(b)fluoranthene	0.089
Benzo(g,h,i)perylene	0.109
Benzo(k)fluoranthene	0.056
Chrysene	0.736
Dibenz(ah)anthracene	<0.030
Fluoranthene	8.95
Fluorene	25.8
Indeno(123-cd)pyrene	0.071
Phenanthrene	35.6
Pyrene	6.35

Other Polynuclear Aromatic Compounds tested:

Carbazole	24.8
Naphthalene	<2.00

The above results are reported in ug/L

All PAH identifications are from retention data only.

Samples were run by a Liquid Chromatographic Technique.

SPECTRIX MONROEVILLE

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020087

Source: AERO. COL. 3 EFF
Description: TREATABILITY STUDY

Date Collected: 02/04/88
Date Received: 02/04/88

Date Extracted: 02/05/88
Date Analyzed: 02/15/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008094

Polynuclear Aromatic Hydrocarbons

Acenaphthene	136
Acenaphthylene	INTERFERENCE
Anthracene	27.3
Benzo(a)anthracene	28.6
Benzo(a)pyrene	7.39
Benzo(b)fluoranthene	11.4
Benzo(g,h,i)perylene	4.89
Benzo(k)fluoranthene	4.10
Chrysene	25.0
Dibenz(ah)anthracene	5.61
Fluoranthene	92.1
Fluorene	82.4
Indeno(123-cd)pyrene	2.98
Phenanthrene	144
Pyrene	86.5

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L.

All PAH identifications are from retention data only.

Samples were run by a Liquid Chromatographic Technique.

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020088

Source: CONT. COL. 1 EFF
Description: TREATABILITY STUDY

Date Collected: 02/04/88
Date Received: 02/04/88

Date Extracted: 02/05/88
Date Analyzed: 02/15/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008095

Polynuclear Aromatic Hydrocarbons

Acenaphthene	44.0
Acenaphthylene	32.7
Anthracene	2.76
Benzo(a)anthracene	0.437
Benzo(a)pyrene	0.026
Benzo(b)fluoranthene	0.043
Benzo(g,h,i)perylene	<0.050
Benzo(k)fluoranthene	<0.020
Chrysene	0.301
Dibenz(ah)anthracene	<0.030
Fluoranthene	5.23
Fluorene	18.1
Indeno(123-cd)pyrene	<0.050
Phenanthrene	26.3
Pyrene	3.53

Other Polynuclear Aromatic Compounds tested:

Carbazole	54.3
Naphthalene	725

The above results are reported in ug/L .

All PAH identifications are from retention data only.

Samples were run by a Liquid Chromatographic Technique

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 03/08/88 AT 14:02 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88020572	AERO. COL. 3 EFF	TREATABILITY STUDY	02/18/88	02/18/88	M8802103
88020573	CONT. COL. 1 EFF	TREATABILITY STUDY	02/18/88	02/18/88	M8802103
88020574	ANAER. COL. 2 EFF	TREATABILITY STUDY	02/18/88	02/18/88	M8802103

008096

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 03/08/89 AT 14:04 PAGE

SAMPLE #	RSLT LNE		SOURCE
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88020572	Phenol, mg/L.....	: 0.555	AERO. COL. 3 EFF
88020573	Phenol, mg/L.....	: 0.206	CONT. COL. 1 EFF
88020574	Phenol, mg/L.....	: 1.16	ANAER. COL. 2 EFF
ORTHOPHOSPHATE			
88020572	Phosphate(o)asP, mg/L	: 3.59	AERO. COL. 3 EFF
88020573	Phosphate(o)asP, mg/L	: <0.100	CONT. COL. 1 EFF
88020574	Phosphate(o)asP, mg/L	: 4.98	ANAER. COL. 2 EFF
TOTAL ORGANIC CARBON			
88020572	TOC, mg/L.....	: 41.6	AERO. COL. 3 EFF
88020573	TOC, mg/L.....	: 10.8	CONT. COL. 1 EFF
88020574	TOC, mg/L.....	: 34.7	ANAER. COL. 2 EFF
pH			
88020572	pH, units.....	: 7.0	AERO. COL. 3 EFF
88020573	pH, units.....	: 6.5	CONT. COL. 1 EFF
88020574	pH, units.....	: 7.5	ANAER. COL. 2 EFF

008097

008097

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020572

Source: AERO. COL. 3 EFF
Description: TREATABILITY STUDY

Date Collected: 02/18/88
Date Received: 02/18/88

Date Extracted: 02/19/88
Date Analyzed: 03/03/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

0080098

Polynuclear Aromatic Hydrocarbons

Acenaphthene	22.5
Acenaphthylene	<2.00
Anthracene	7.19
Benzo(a)anthracene	15.7
Benzo(a)pyrene	4.12
Benzo(b)fluoranthene	6.01
Benzo(g,h,i)perylene	3.91
Benzo(k)fluoranthene	2.22
Chrysene	14.2
Dibenz(ah)anthracene	6.59
Fluoranthene	49.3
Fluorene	9.68
Indeno(123-cd)pyrene	2.48
Phenanthrene	1.84
Pyrene	39.3

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020573

Source: CONT. COL. 1 EFF
Description: TREATABILITY STUDY

Date Collected: 02/18/88
Date Received: 02/18/88

Date Extracted: 02/19/88
Date Analyzed: 03/03/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008099

Polynuclear Aromatic Hydrocarbons

Acenaphthene	40.5
Acenaphthylene	28.2
Anthracene	2.85
Benzo(a)anthracene	0.068
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(g,h,i)perylene	<0.050
Benzo(k)fluoranthene	<0.020
Chrysene	<0.150
Dibenz(ah)anthracene	<0.030
Fluoranthene	3.16
Fluorene	19.3
Indeno(123-cd)pyrene	<0.050
Phenanthrene	26.0
Pyrene	2.38

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	670

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020574

Source: ANAER. COL. 2 EFF
Description: TREATABILITY STUDY

Date Collected: 02/18/88
Date Received: 02/18/88

Date Extracted: 02/19/88
Date Analyzed: 03/03/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008100

Polynuclear Aromatic Hydrocarbons

Acenaphthene	70.4
Acenaphthylene	INTERFERENCE
Anthracene	5.31
Benzo(a)anthracene	0.805
Benzo(a)pyrene	0.148
Benzo(b)fluoranthene	0.247
Benzo(g,h,i)perylene	0.130
Benzo(k)fluoranthene	0.088
Chrysene	0.570
Dibenz(ah)anthracene	<0.030
Fluoranthene	8.36
Fluorene	30.7
Indeno(123-cd)pyrene	0.085
Phenanthrene	10.6
Pyrene	6.75

Other Polynuclear Aromatic Compounds tested:

Carbazole	7.08
Naphthalene	4.30

The above results are reported in ug/L.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 03/23/88 AT 16:33 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88030075	CONT. COL. 1 EFF	TREATABILITY STUDY	03/03/88	03/03/88	M8803017
88030076	ANAER. COL. 2 EFF	TREATABILITY STUDY	03/03/88	03/03/88	M8803017
88030077	AERO. COL. 3 EFF	TREATABILITY STUDY	03/03/88	03/03/88	M8803017

008101

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 03/23/88 AT 16:35 PAGE

SAMPLE #	RSLT. LNE		SOURCE
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88030075	Phenol, mg/L.....	0.137	CONT. COL. 1 EFF
88030076	Phenol, mg/L..... :	1.20	ANAER. COL. 2 EFF
98030077	Phenol, mg/L..... :	0.297	AERO. COL. 3 EFF
ORTHOPHOSPHATE AS P			
88030075	Phosphate(o)asP, mg/L :	<0.100	CONT. COL. 1 EFF
88030076	Phosphate(o)asP, mg/L :	4.39	ANAER. COL. 2 EFF
88030077	Phosphate(o)asP, mg/L :	3.56	AERO. COL. 3 EFF
TOTAL ORGANIC CARBON			
98030075	TOC, mg/L..... :	10.2	CONT. COL. 1 EFF
88030076	TOC, mg/L..... :	32.7	ANAER. COL. 2 EFF
88030077	TOC, mg/L..... :	33.7	AERO. COL. 3 EFF
PH			
98030075	pH, units..... :	7.2	CONT. COL. 1 EFF
88030076	pH, units..... :	7.6	ANAER. COL. 2 EFF
88030077	pH, units..... :	7.1	AERO. COL. 3 EFF

008102

008102

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88030073

Source: CONT. COL. 1 EFF
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/09/88
Date Analyzed: 03/19/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008103

Polynuclear Aromatic Hydrocarbons

Acenaphthene	37.0
Acenaphthylene	60.3
Anthracene	1.84
Benzo(a)anthracene	0.089
Benzo(a)pyrene	<0.020
Benzo(b)fluoranthene	<0.020
Benzo(g,h,i)perylene	<0.050
Benzo(k)fluoranthene	<0.020
Chrysene	<0.150
Dibenz(ah)anthracene	<0.030
Fluoranthene	1.97
Fluorene	17.0
Indeno(123-cd)pyrene	<0.050
Phenanthrene	19.0
Pyrene	1.47

Other Polynuclear Aromatic Compounds tested:

Carbazole	82.4
Naphthalene	496

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88030076

Source: ANAER. COL. 2 EFF
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/09/88
Date Analyzed: 03/19/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008104

Polynuclear Aromatic Hydrocarbons

Acenaphthene	31.7
Acenaphthylene	8.25
Anthracene	2.38
Benzo(a)anthracene	0.770
Benzo(a)pyrene	0.078
Benzo(b)fluoranthene	0.063
Benzo(g,h,i)perylene	<0.050
Benzo(k)fluoranthene	0.048
Chrysene	0.690
Dibenz(ah)anthracene	<0.030
Fluoranthene	9.82
Fluorene	12.8
Indeno(123-cd)pyrene	<0.050
Phenanthrene	<0.500
Pyrene	3.89

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 8803007

Source: AERO. COL. 3 EFF
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/09/88
Date Analyzed: 03/19/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008105

Polynuclear Aromatic Hydrocarbons

Acenaphthene	18.5
Acenaphthylene	<2.00
Anthracene	4.54
Benzo(a)anthracene	5.95
Benzo(a)pyrene	7.90
Benzo(b)fluoranthene	12.6
Benzo(g,h,i)perylene	11.4
Benzo(k)fluoranthene	4.70
Chrysene	7.34
Dibenz(ah)anthracene	14.1
Fluoranthene	22.5
Fluorene	2.27
Indeno(123-cd)pyrene	8.72
Phenanthrene	3.80
Pyrene	57.5

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L .

All PAH identifications are from retention data only.

APPENDIX 12

FINAL SOIL COLUMN SOIL RESULTS

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 03/30/88 AT 09:00 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	QRD #
88030078	AERO. SOIL	TREATABILITY STUDY	03/03/88	03/03/88	M8803018
88030079	ANAER. SOIL	TREATABILITY STUDY	03/03/88	03/03/88	M8803018
88030080	CONTROL SOIL	TREATABILITY STUDY	03/03/88	03/03/88	M8803018

008107

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KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 03/30/88 AT 09:06 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
% MOISTURE			
88030078	% Solids @103 C.....	: 79.1	AERO. SOIL
88030079	% Solids @103 C.....	: 77.4	ANAER. SOIL
88030080	% Solids @103 C.....	: 78.7	CONTROL SOIL
METHYLENE CHLORIDE EXTRACTABLES			
88030078	MeCl Extractables, mg/Kg	: 865	AERO. SOIL
88030079	MeCl Extractables, mg/Kg	: 1960	ANAER. SOIL
88030080	MeCl Extractables, mg/Kg	: 2960	CONTROL SOIL
TOTAL ORGANIC CARBON			
88030078	% TOC.....	: 0.69	AERO. SOIL
88030079	% TOC.....	: 1.13	ANAER. SOIL
88030080	% TOC.....	: 1.10	CONTROL SOIL
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
88030078	Oil & Grease, mg/Kg.....	: 7240	AERO. SOIL
88030079	Oil & Grease, mg/Kg.....	: 8390	ANAER. SOIL
88030080	Oil & Grease, mg/Kg.....	: 8830	CONTROL SOIL
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88030078	Phenol, mg/Kg.....	: 2.60	AERO. SOIL
88030079	Phenol, mg/Kg.....	: 2.92	ANAER. SOIL
88030080	Phenol, mg/Kg.....	: 1.42	CONTROL SOIL
TOTAL PHOSPHOROUS AS P			
88030078	Phosphorous, mg/Kg.....	: 62.0	AERO. SOIL
88030079	Phosphorous, mg/Kg.....	: 77.0	ANAER. SOIL
88030080	Phosphorous, mg/Kg.....	: <50.0	CONTROL SOIL
pH			
88030078	Soil pH, units.....	: 7.34	AERO. SOIL
88030079	Soil pH, units.....	: 8.19	ANAER. SOIL
88030080	Soil pH, units.....	: 7.69	CONTROL SOIL
TOTAL KJELDAHL NITROGEN			
88030078	TKN as N, mg/Kg.....	: 198	AERO. SOIL
88030079	TKN as N, mg/Kg.....	: 225	ANAER. SOIL
88030080	TKN as N, mg/Kg.....	: 219	CONTROL SOIL

The above results are on an as received basis.

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KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 2: SUMMARY OF METALS DATA — PRODUCED ON 03/30/88 AT 09:07 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
ANTIMONY			
38030078	Antimony, ug/Kg.....	<6000	AERO. SOIL
38030079	Antimony, ug/Kg.....	<6000	ANAER. SOIL
38030080	Antimony, ug/Kg.....	<6000	CONTROL SOIL
ARSENIC			
38030078	Arsenic, ug/Kg.....	7140	AERO. SOIL
38030079	Arsenic, ug/Kg.....	15300	ANAER. SOIL
38030080	Arsenic, ug/Kg.....	40100	CONTROL SOIL
BERYLLIUM			
38030078	Beryllium, ug/Kg....	1030	AERO. SOIL
38030079	Beryllium, ug/Kg....	1070	ANAER. SOIL
38030080	Beryllium, ug/Kg....	1070	CONTROL SOIL
CADMIUM			
38030078	Cadmium, ug/Kg.....	<500	AERO. SOIL
38030079	Cadmium, ug/Kg.....	<500	ANAER. SOIL
38030080	Cadmium, ug/Kg.....	<500	CONTROL SOIL
CHROMIUM			
38030078	Chromium, ug/Kg.....	9120	AERO. SOIL
38030079	Chromium, ug/Kg.....	95800	ANAER. SOIL
38030080	Chromium, ug/Kg.....	15200	CONTROL SOIL
COPPER			
38030078	Copper, ug/Kg.....	3570	AERO. SOIL
38030079	Copper, ug/Kg.....	6140	ANAER. SOIL
38030080	Copper, ug/Kg.....	7240	CONTROL SOIL
LEAD			
38030078	Lead, ug/Kg.....	4330	AERO. SOIL
38030079	Lead, ug/Kg.....	5870	ANAER. SOIL
38030080	Lead, ug/Kg.....	6190	CONTROL SOIL
MERCURY			
38030078	Mercury, ug/Kg.....	1970	AERO. SOIL
38030079	Mercury, ug/Kg.....	2360	ANAER. SOIL
38030080	Mercury, ug/Kg.....	1370	CONTROL SOIL
NICKEL			
38030078	Nickel, ug/Kg.....	<4000	AERO. SOIL
38030079	Nickel, ug/Kg.....	<4000	ANAER. SOIL
38030080	Nickel, ug/Kg.....	<4000	CONTROL SOIL
SELENIUM			
38030078	Selenium, ug/Kg.....	<500	AERO. SOIL
38030079	Selenium, ug/Kg.....	<500	ANAER. SOIL
38030080	Selenium, ug/Kg.....	<500	CONTROL SOIL
SILVER			
38030078	Silver, ug/Kg.....	<1000	AERO. SOIL
38030079	Silver, ug/Kg.....	<1000	ANAER. SOIL
38030080	Silver, ug/Kg.....	<1000	CONTROL SOIL
THALLIUM			
38030078	Thallium, ug/Kg.....	<1000	AERO. SOIL
38030079	Thallium, ug/Kg.....	<1000	ANAER. SOIL
38030080	Thallium, ug/Kg.....	<1000	CONTROL SOIL

The above results are on a dry weight basis.

008109

008109

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 2: SUMMARY OF METALS DATA PRODUCED ON 03/30/88 AT 09:07 PAGE

SAMPLE #	RSLT. LNE		SOURCE
ZINC			
88030078	Zinc, ug/Kg..... :	27100	AERO. SOIL
88030079	Zinc, ug/Kg..... :	122000	ANAER. SOIL
88030080	Zinc, ug/Kg..... :	37700	CONTROL SOIL

The above results are on a dry weight basis.

008110

008110

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 3: SUMMARY OF METALS DATA — PRODUCED ON 03/30/88 AT 09:07 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
TCLP LEACHATE			
ARSENIC			
88030078	Arsenic, mg/L..... :	<0.500	AERO. SOIL
88030079	Arsenic, mg/L..... :	<0.500	ANAER. SOIL
88030080	Arsenic, mg/L..... :	<0.500	CONTROL SOIL
COPPER			
88030078	Copper, mg/L..... :	<0.025	AERO. SOIL
88030079	Copper, mg/L..... :	<0.025	ANAER. SOIL
88030080	Copper, mg/L..... :	<0.025	CONTROL SOIL
CHROMIUM			
88030078	Chromium, mg/L..... :	<0.010	AERO. SOIL
88030079	Chromium, mg/L..... :	<0.010	ANAER. SOIL
88030080	Chromium, mg/L..... :	<0.010	CONTROL SOIL

008111

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 4: SUMMARY OF METALS DATA — PRODUCED ON 03/30/88 AT 09:07 — PAGE :

SAMPLE #	RSLT. LNE		SOURCE
EPTOX LEACHATE			
ARSENIC			
8030078	Arsenic, mg/L.....	<0.500	AERO. SOIL
8030079	Arsenic, mg/L.....	<0.500	ANAER. SOIL
8030080	Arsenic, mg/L.....	<0.500	CONTROL SOIL
BARIUM			
8030078	Barium, mg/L.....	<0.200	AERO. SOIL
8030079	Barium, mg/L.....	<0.200	ANAER. SOIL
8030080	Barium, mg/L.....	<0.200	CONTROL SOIL
CADMIUM			
8030078	Cadmium, mg/L.....	<0.005	AERO. SOIL
8030079	Cadmium, mg/L.....	<0.005	ANAER. SOIL
8030080	Cadmium, mg/L.....	<0.005	CONTROL SOIL
CHROMIUM			
8030078	Chromium, mg/L.....	<0.010	AERO. SOIL
8030079	Chromium, mg/L.....	<0.010	ANAER. SOIL
8030080	Chromium, mg/L.....	<0.010	CONTROL SOIL
COPPER			
8030078	Copper, mg/L.....	<0.025	AERO. SOIL
8030079	Copper, mg/L.....	<0.025	ANAER. SOIL
8030080	Copper, mg/L.....	<0.025	CONTROL SOIL
LEAD			
8030078	Lead, mg/L.....	<0.100	AERO. SOIL
8030079	Lead, mg/L.....	<0.100	ANAER. SOIL
8030080	Lead, mg/L.....	<0.100	CONTROL SOIL
MERCURY			
8030078	Mercury, mg/L.....	<0.0002	AERO. SOIL
8030079	Mercury, mg/L.....	<0.0002	ANAER. SOIL
8030080	Mercury, mg/L.....	<0.0002	CONTROL SOIL
SELENIUM			
8030078	Selenium, mg/L.....	<0.500	AERO. SOIL
8030079	Selenium, mg/L.....	<0.500	ANAER. SOIL
8030080	Selenium, mg/L.....	<0.500	CONTROL SOIL
SILVER			
8030078	Silver, mg/L.....	<0.010	AERO. SOIL
8030079	Silver, mg/L.....	<0.010	ANAER. SOIL
8030080	Silver, mg/L.....	<0.010	CONTROL SOIL

008112

008112

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 5: SUMMARY OF PAH DATA

Sample: 88030078

Source: AERO. SOIL
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/08/88
Date Analyzed: 03/17/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008113

Polynuclear Aromatic Hydrocarbons

Acenaphthene	379000
Acenaphthylene	82600
Anthracene	177000
Benzo(a)anthracene	111000
Benzo(a)pyrene	34200
Benzo(b)fluoranthene	51200
Benzo(g,h,i)perylene	43500
Benzo(k)fluoranthene	19000
Chrysene	106000
Dibenz(ah)anthracene	61000
Fluoranthene	352000
Fluorene	254000
Indeno(123-cd)pyrene	30500
Phenanthrene	685000
Pyrene	317000

Other Polynuclear Aromatic Compounds tested:

Carbazole	16400
Naphthalene	729000

The above results are reported in ug/Kg.

The above results are on an as received basis.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 5: SUMMARY OF PAH DATA

Sample: 88030079

Source: ANAER. SOIL
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/08/88
Date Analyzed: 03/17/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

Polynuclear Aromatic Hydrocarbons

Acenaphthene	458000
Acenaphthylene	7300
Anthracene	50200
Benzo(a)anthracene	44300
Benzo(a)pyrene	20000
Benzo(b)fluoranthene	30700
Benzo(g,h,i)perylene	20100
Benzo(k)fluoranthene	10800
Chrysene	41400
Dibenz(ah)anthracene	35400
Fluoranthene	161000
Fluorene	108000
Indeno(123-cd)pyrene	13100
Phenanthrene	253000
Pyrene	139000

Other Polynuclear Aromatic Compounds tested:

Carbazole	63000
Naphthalene	114000

The above results are reported in ug/Kg.

The above results are on an as received basis.

All PAH identifications are from retention data only.

008114

008114

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 5: SUMMARY OF PAH DATA

Sample: 88030080

Source: CONTROL SOIL
Description: TREATABILITY STUDY

Date Collected 03/03/88
Date Received 03/03/88

Date Extracted 03/08/88
Date Analyzed 03/17/88

Clean up Method

silica gel clean-up ✓ yes ___ no
florisil clean-up ___ yes ___ no
alumina clean-up ___ yes ___ no
sulfur clean-up ___ yes ___ no

Polynuclear Aromatic Hydrocarbons

Acenaphthene	:	49300
Acenaphthylene	:	<1000
Anthracene	:	1750
Benzo(a)anthracene	:	4300
Benzo(a)pyrene	:	1670
Benzo(b)fluoranthene	:	2880
Benzo(g,h,i)perylene	:	1520
Benzo(k)fluoranthene	:	850
Chrysene	:	3860
Dibenz(ah)anthracene	:	1950
Fluoranthene	:	5530
Fluorene	:	4220
Indeno(123-cd)pyrene	:	1240
Phenanthrene	:	9170
Pyrene	:	5360

Other Polynuclear Aromatic Compounds tested:

Carbazole	:	8430
Naphthalene	:	8910

The above results are reported in ug/Kg.

The above results are on an as received basis.

All PAH identifications are from retention data only.

008115

008115

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 6: SUMMARY OF PAH DATA

Sample: 88030078

Source: AERO. SOIL
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/11/88
Date Analyzed: 03/17/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

TCLP EXTRACT

Polynuclear Aromatic Hydrocarbons

Acenaphthere	475
Acenaphthylene	197
Anthracene	25.9
Benzo(a)anthracene	3.00
Benzo(a)pyrene	0.569
Benzo(b)fluoranthene	0.956
Benzo(g,h,i)perylene	0.391
Benzo(k)fluoranthene	0.333
Chrysene	2.24
Dibenz(ah)anthracene	0.439
Fluoranthene	32.4
Fluorene	219
Indeno(123-cd)pyrene	0.262
Phenanthrene	235
Pyrene	23.4

Other Polynuclear Aromatic Compounds tested:

Carbazole	198
Naphthalene	3290

The above results are reported in ug/L .

All PAH identifications are from retention data only.

0081116

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 6: SUMMARY OF PAH DATA

Sample: 88030079

Source: ANAER. SOIL
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/11/88
Date Analyzed: 03/17/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

TCLP EXTRACT

Polynuclear Aromatic Hydrocarbons

Acenaphthene	599
Acenaphthylene	359
Anthracene	25.5
Benzo(a)anthracene	2.39
Benzo(a)pyrene	0.296
Benzo(b)fluoranthene	0.478
Benzo(g,h,i)perylene	0.272
Benzo(k)fluoranthene	0.172
Chrysene	1.78
Dibenz(ah)anthracene	0.293
Fluoranthene	28.0
Fluorene	246
Indeno(123-cd)pyrene	0.177
Phenanthrene	248
Pyrene	19.8

Other Polynuclear Aromatic Compounds tested:

Carbazole	109
Naphthalene	5950

The above results are reported in ug/L .

All PAH identifications are from retention data only.

008117

TABLE 6: SUMMARY OF PAH DATA

Sample: 88030080

Source: CONTROL SOIL
Description: TREATABILITY STUDY

Date Collected: 03/03/88
Date Received: 03/03/88

Date Extracted: 03/11/88
Date Analyzed: 03/17/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008118

TCLP EXTRACT

Polynuclear Aromatic Hydrocarbons

Acenaphthene	739
Acenaphthylene	435
Anthracene	29.8
Benzo(a)anthracene	2.03
Benzo(a)pyrene	0.163
Benzo(b)fluoranthene	0.143
Benzo(g,h,i)perylene	0.174
Benzo(k)fluoranthene	0.095
Chrysene	1.66
Dibenz(ah)anthracene	0.122
Fluoranthene	33.4
Fluorene	299
Indeno(123-cd)pyrene	0.113
Phenanthrene	306
Pyrene	23.0

Other Polynuclear Aromatic Compounds tested:

Carbazole	19.3
Naphthalene	7260

The above results are reported in ug/L .

All PAH identifications are from retention data only.

APPENDIX 13

SLURRY REACTOR RESULTS

APPENDIX 13

SECTION 1

INITIAL SOIL AND GROUNDWATER RESULTS

008120

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS

PRODUCED ON 02/01/88 AT 13:54 PAGE 1

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88010187	SR SOIL	TREATABILITY STUDY	01/13/88	01/13/88	M8801058

008121

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 02/01/88 AT 13:57 PAGE

SAMPLE #	RSLT. LNE		SOURCE
% MOISTURE			
88010187	% Solids @103 C..... :	86.7	SR SOIL
pH			
88010187	Soil pH, units..... :	8.53	SR SOIL

The above results are on an as received basis.

008122

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88010187

Source: SR SOIL
Description: TREATABILITY STUDY

Date Collected: 01/13/88
Date Received: 01/13/88

Date Extracted: 01/14/88
Date Analyzed: 01/23/88

Clean up Method

silica gel clean-up	___yes	___no
florisil clean-up	___yes	___no
alumina clean-up	___yes	___no
sulfur clean-up	___yes	___no

008123

Polynuclear Aromatic Hydrocarbons

Acenaphthene	475000
Acenaphthylene	INTERFERENCE
Anthracene	7250
Benzo(a)anthracene	12700
Benzo(a)pyrene	8840
Benzo(b)fluoranthene	13300
Benzo(g,h,i)perylene	11300
Benzo(k)fluoranthene	4000
Chrysene	10900
Dibenz(ah)anthracene	15200
Flucranthene	24600
Fluorene	35200
Indeno(123-cd)pyrene	7660
Phenanthrene	32300
Pyrene	INTERFERENCE

Other Polynuclear Aromatic Compounds tested:

Carbazole	110000
Naphthalene	45500

The above results are reported in ug/kg.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 01/27/88 AT 16:19 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88010186	SR WATER	TREATABILITY STUDY	01/13/88	01/13/88	M8801057

008124

APPENDIX 12

INITIAL SOIL COLUMN SOIL RESULTS

SEEDED = AEROBIC AND ANAEROBIC SOIL COLUMNS
UNSEEDED = CONTROL COLUMN

008125

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 02/08/88 AT 10:44 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88010125	SEEDED COL.	TREATABILITY STUDY	01/11/88	01/11/88	M8801041
88010126	RAW COL	TREATABILITY STUDY	01/11/88	01/11/88	M8801041

008126

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 1: SUMMARY OF ANALYTICAL DATA — PRODUCED ON 02/08/88 AT 10 47 — PAGE

SAMPLE #	RSLT LNE		SOURCE
TOTAL ORGANIC CARBON			
88010125	% TOC	1.53	SEEDED COL
88010126	% TOC	2.00	RAW COL.
OIL & GREASE, TOTAL RECOVERABLE, GRAVIMETRIC			
88010125	Oil & Grease, mg/Kg	66.7	SEEDED COL
88010126	Oil & Grease, mg/Kg	4830	RAW COL
TOTAL RECOVERABLE PHENOLICS (AS PHENOL)			
88010125	Phenol, mg/Kg	31.5	SEEDED COL
88010126	Phenol, mg/Kg	30.8	RAW COL
PHOSPHOROUS			
88010125	Phosphorous, mg/Kg	<10.0	SEEDED COL.
88010126	Phosphorous, mg/Kg	<10.0	RAW COL.
pH			
88010125	Soil pH, units	7.96	SEEDED COL.
88010126	Soil pH, units	8.39	RAW COL
TOTAL KJELDAHL NITROGEN			
88010125	TKN as N, mg/Kg	197	SEEDED COL.
88010126	TKN as N, mg/Kg	128	RAW COL.
% MOISTURE			
88010125	% Solids @103 C	77.9	SEEDED COL
88010126	% Solids @103 C	86.5	RAW COL
METHYLENE CHLORIDE EXTRACTABLES			
88010125	MeCl Extractables, mg/Kg	280	SEEDED COL.
88010126	MeCl Extractables, mg/Kg	10400	RAW COL.

The above results are on an as received basis.

008127

008127

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF METALS DATA — PRODUCED ON 02/08/88 AT 10:48 — PAGE

SAMPLE #	RSLT LNE		SOURCE
TOTAL METALS			
ANTIMONY			
88010125	Antimony, ug/Kg.... :	<6000	SEEDED COL.
88010126	Antimony, ug/Kg.... :	<6000	RAW COL
ARSENIC			
88010125	Arsenic, ug/Kg..... :	38400	SEEDED COL.
88010126	Arsenic, ug/Kg..... :	9480	RAW COL.
BERYLLIUM			
88010125	Beryllium, ug/Kg... :	<500	SEEDED COL
88010126	Beryllium, ug/Kg... :	<500	RAW COL.
CADMIUM			
88010125	Cadmium, ug/Kg..... :	<500	SEEDED COL.
88010126	Cadmium, ug/Kg..... :	<500	RAW COL.
CHROMIUM			
88010125	Chromium, ug/Kg.... :	22400	SEEDED COL.
88010126	Chromium, ug/Kg.... :	77600	RAW COL.
COPPER			
88010125	Copper, ug/Kg..... :	<2500	SEEDED COL.
88010126	Copper, ug/Kg..... :	2530	RAW COL.
LEAD			
88010125	Lead, ug/Kg..... :	4820	SEEDED COL.
88010126	Lead, ug/Kg..... :	6450	RAW COL.
MERCURY			
88010125	Mercury, ug/Kg..... :	<100	SEEDED COL.
88010126	Mercury, ug/Kg..... :	<100	RAW COL.
NICKEL			
88010125	Nickel, ug/Kg..... :	<4000	SEEDED COL.
88010126	Nickel, ug/Kg..... :	<4000	RAW COL.
SELENIUM			
88010125	Selenium, ug/Kg.... :	<500	SEEDED COL.
88010126	Selenium, ug/Kg.... :	<500	RAW COL.
SILVER			
88010125	Silver, ug/Kg..... :	<1000	SEEDED COL.
88010126	Silver, ug/Kg..... :	<1000	RAW COL.
CATIONIC EXCHANGE CAPACITY			
88010125	Sodium, ug/Kg..... :	63.1	SEEDED COL.
88010126	Sodium, ug/Kg..... :	71.5	RAW COL.
THALLIUM			
88010125	Thallium, ug/Kg.... :	<1000	SEEDED COL.
88010126	Thallium, ug/Kg.... :	<1000	RAW COL.
ZINC			
88010125	Zinc, ug/Kg..... :	73800	SEEDED COL.
88010126	Zinc, ug/Kg..... :	144000	RAW COL.

The above results are on a dry weight basis.

008128

008128

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 2: SUMMARY OF METALS DATA — PRODUCED ON 02/08/88 AT 10.48 — PAGE

SAMPLE #	RSLT. LNE		SOURCE
EPTOX METALS			
ARSENIC			
88010125	Arsenic, mg/L.	<0.500	SEEDED COL.
88010126	Arsenic, mg/L.	<0.500	RAW COL.
BARIUM			
88010125	Barium, mg/L.	<0.200	SEEDED COL.
88010126	Barium, mg/L.	<0.200	RAW COL.
CADMIUM			
88010125	Cadmium, mg/L.	<0.005	SEEDED COL.
88010126	Cadmium, mg/L. . . .	<0.005	RAW COL.
CHROMIUM			
88010125	Chromium, mg/L.	<0.010	SEEDED COL.
88010126	Chromium, mg/L. . .	<0.010	RAW COL.
COPPER			
88010125	Copper, mg/L.	<0.025	SEEDED COL.
88010126	Copper, mg/L. . . .	<0.025	RAW COL.
LEAD			
88010125	Lead, mg/L.	<0.100	SEEDED COL.
88010126	Lead, mg/L.	<0.100	RAW COL.
MERCURY			
88010125	Mercury, mg/L.	<0.0002	SEEDED COL.
88010126	Mercury, mg/L. . . .	<0.0002	RAW COL.
SELENIUM			
88010125	Selenium, mg/L.	<0.500	SEEDED COL.
88010126	Selenium, mg/L.	<0.500	RAW COL.
SILVER			
88010125	Silver, mg/L.	<0.010	SEEDED COL.
88010126	Silver, mg/L.	<0.010	RAW COL.
TCLP METALS			
ARSENIC			
88010125	Arsenic, mg/L.	<0.500	SEEDED COL.
88010126	Arsenic, mg/L.	<0.500	RAW COL.
CHROMIUM			
88010125	Chromium, mg/L.	<0.010	SEEDED COL.
88010126	Chromium, mg/L. . . .	<0.010	RAW COL.
COPPER			
88010125	Copper, mg/L.	<0.025	SEEDED COL.
88010126	Copper, mg/L.	<0.025	RAW COL.

008129

008129

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 3: SUMMARY OF PAH DATA

Sample: 88010125

Source: SEEDED COL.
Description: TREATABILITY STUDY

Date Collected: 01/11/88
Date Received: 01/11/88

Date Extracted: 01/12/88
Date Analyzed: 01/22/88

Clean up Method

silica gel clean-up ___yes ___no
florisil clean-up ___yes ___no
alumina clean-up ___yes ___no
sulfur clean-up ___yes ___no

008130

Polynuclear Aromatic Hydrocarbons

Acenaphthene	:	150000
Acenaphthylene	:	<1000
Anthracene	:	27300
Benzo(a)anthracene	:	15500
Benzo(a)pyrene	:	8220
Benzo(b)fluoranthene	:	11100
Benzo(g,h,i)perylene	:	8100
Benzo(k)fluoranthene	:	3890
Chrysene	:	12700
Dibenz(ah)anthracene	:	7760
Fluoranthene	:	64800
Fluorene	:	53500
Indeno(123-cd)pyrene	:	4010
Phenanthrene	:	126000
Pyrene	:	104000

Other Polynuclear Aromatic Compounds tested:

Carbazole	:	29600
Naphthalene	:	108000

The above results are reported in ug/Kg.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 3: SUMMARY OF PAH DATA

Sample: 88010126

Source: RAW COL.
Description: TREATABILITY STUDY

Date Collected: 01/11/88
Date Received: 01/11/88

Date Extracted: 01/12/88
Date Analyzed: 01/22/88

Clean up Method

silica gel clean-up ___yes ___no
florisil clean-up ___yes ___no
alumina clean-up ___yes ___no
sulfur clean-up ___yes ___no

Polynuclear Aromatic Hydrocarbons

Acenaphthene	670000
Acenaphthylene	<1000
Anthracene	107000
Benzo(a)anthracene	83800
Benzo(a)pyrene	43700
Benzo(b)fluoranthene	60700
Benzo(g,h,i)perylene	90800
Benzo(k)fluoranthene	21600
Chrysene	67300
Dibenz(ah)anthracene	62100
Fluoranthene	272000
Fluorene	192000
Indeno(123-cd)pyrene	41600
Phenanthrene	442000
Pyrene	387000

Other Polynuclear Aromatic Compounds tested:

Carbazole	151000
Naphthalene	154000

The above results are reported in ug/Kg.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 4: SUMMARY OF PAH DATA

Sample: 88010125

Source: SEEDED COL.
Description: TREATABILITY STUDY

Date Collected: 01/11/88
Date Received: 01/11/88

Date Extracted: 01/14/88
Date Analyzed: 01/20/88

Clean up Method

silica gel clean-up	___yes	___no
florisil clean-up	___yes	___no
alumina clean-up	___yes	___no
sulfur clean-up	___yes	___no

TCLP EXTRACT

Polynuclear Aromatic Hydrocarbons

Acenaphthene	229
Acenaphthylene	206
Anthracene	24.2
Benzo(a)anthracene	3.76
Benzo(a)pyrene	1.35
Benzo(b)fluoranthene	2.11
Benzo(g,h,i)perylene	1.83
Benzo(k)fluoranthene	0.739
Chrysene	3.01
Dibenz(ah)anthracene	1.86
Fluoranthene	23.8
Fluorene	190
Indeno(123-cd)pyrene	0.912
Phenanthrene	220
Pyrene	28.8

Other Polynuclear Aromatic Compounds tested:

Carbazole	16.3
Naphthalene	5410

The above results are reported in ug/L.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 4: SUMMARY OF PAH DATA

Sample: 88010126

Source: RAW COL.
Description: TREATABILITY STUDY

Date Collected: 01/11/88
Date Received: 01/11/88

Date Extracted: 01/14/88
Date Analyzed: 01/20/88

Clean up Method

silica gel clean-up	___yes	___no
florisil clean-up	___yes	___no
alumina clean-up	___yes	___no
sulfur clean-up	___yes	___no

TCLP EXTRACT

Polynuclear Aromatic Hydrocarbons

Acenaphthene	211
Acenaphthylene	171
Anthracene	23.0
Benzo(a)anthracene	2.24
Benzo(a)pyrene	0.607
Benzo(b)fluoranthene	0.911
Benzo(g,h,i)perylene	0.616
Benzo(k)fluoranthene	0.307
Chrysene	1.80
Dibenz(ah)anthracene	0.590
Fluoranthene	29.5
Fluorene	188
Indeno(123-cd)pyrene	0.314
Phenanthrene	224
Pyrene	28.8

Other Polynuclear Aromatic Compounds tested:

Carbazole	130
Naphthalene	2670

The above results are reported in ug/L .

All PAH identifications are from retention data only.

008133

008133

APPENDIX A

ACTIVATED SLUDGE TREATMENT PROCESS:

SUMMARY OF CASE STUDIES

Reference Keystone Environmental Resources, Inc., Internal Data Base, Keystone Environmental Resources, Inc., a subsidiary of Koppers Company, Inc., Monroeville, PA.

A1 OPERATING CONDITIONS

The 19 activated sludge treatment process case studies were conducted within the operating conditions listed below.

Hydraulic Retention Time (HRT):	1 - 10 days
Solid Retention Time (SRT):	20 - 100 days
Mixed Liquor Temperature:	20 - 30°C
pH Control (Mixed Liquor):	6.5 - 7.5 units
Mixed Liquor Dissolved Oxygen:	3 - 8 mg/l
Recycle Ratio (Recycle: Influent):	Up to 2.0
Nutrient Addition (N,P):	As required

Performance data for all 19 cases was obtained from Keystone Environmental Resources internal data base[6]. This data base has been developed from data collected by Keystone during the past 10 years.

008135

A2

PERFORMANCE DATA

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020338

Date Collected: 02/10/88
Date Received: 02/11/88

Source: SR AN WATER
Description: SLURRY REACTOR

Date Extracted: 02/12/88
Date Analyzed: 02/24/88

Clean up Method

silica gel clean-up	✓ yes	no
florisil clean-up	yes	no
alumina clean-up	yes	no
sulfur clean-up	yes	no

008137

Polynuclear Aromatic Hydrocarbons

Acenaphthene	84.5
Acenaphthylene	INTERFERENCE
Anthracene	8.39
Benzo(a)anthracene	5.46
Benzo(a)pyrene	1.39
Benzo(b)fluoranthene	2.05
Benzo(g,h,i)perylene	5.33
Benzo(k)fluoranthene	0.775
Chrysene	5.19
Dibenz(ah)anthracene	4.29
Fluoranthene	19.7
Fluorene	45.0
Indeno(123-cd)pyrene	3.62
Phenanthrene	72.4
Pyrene	17.1

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	<2.00

The above results are reported in ug/L .

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 01/27/88 AT 16:20 PAGE

SAMPLE #	RSLT. LNE	SOURCE
pH		
88010186	pH, units..... : 7.4	SR WATER

008138

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88010186

Source: SR WATER
Description: TREATABILITY STUDY

Date Collected: 01/13/88
Date Received: 01/13/88

Date Extracted: 01/14/88
Date Analyzed: 01/20/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

Polynuclear Aromatic Hydrocarbons

Acenaphthene	47.5
Acenaphthylene	73.6
Anthracene	8.83
Benzo(a)anthracene	3.61
Benzo(a)pyrene	1.12
Benzo(b)fluoranthene	1.64
Benzo(g,h,i)perylene	1.22
Benzo(k)fluoranthene	0.574
Chrysene	3.93
Dibenz(ah)anthracene	1.34
Fluoranthene	28.3
Fluorene	35.0
Indeno(123-cd)pyrene	0.584
Phenanthrene	64.8
Pyrene	38.8

Other Polynuclear Aromatic Compounds tested:

Carbazole	90.6
Naphthalene	1910

The above results are reported in ug/L .

All PAH identifications are from retention data only.

APPENDIX 13

SECTION 2

FINAL SOIL AND GROUNDWATER RESULTS

008140

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 03/02/88 AT 10:30 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88020339	SR AER SOIL	SLURRY REACTOR	02/10/88	02/11/88	M8802059
88020340	SR AN SOIL	SLURRY REACTOR	02/10/88	02/11/88	M8802059

008141

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 03/02/88 AT 10:32 PAGE

SAMPLE #	RSLT. LNE		SOURCE
% MOISTURE			
88020339	% Solids @103 C..... :	74.1	SR AER SOIL
88020340	% Solids @103 C..... :	77.6	SR AN SOIL
pH			
88020339	Soil pH, units..... :	7.22	SR AER SOIL
88020340	Soil pH, units..... :	7.33	SR AN SOIL

The above results are on an as received basis.

008142

008142

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020339

Source: SR AER SOIL
Description: SLURRY REACTOR

Date Collected: 02/10/88
Date Received: 02/11/88

Date Extracted: 02/15/88
Date Analyzed: 02/24/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008143

Polynuclear Aromatic Hydrocarbons

Acenaphthene	246000
Acenaphthylene	<1000
Anthracene	74200
Benzo(a)anthracene	59900
Benzo(a)pyrene	25000
Benzo(b)fluoranthene	35200
Benzo(g,h,i)perylene	38000
Benzo(k)fluoranthene	13600
Chrysene	60400
Dibenz(ah)anthracene	73200
Fluoranthene	240000
Fluorene	103000
Indeno(123-cd)pyrene	26200
Phenanthrene	220000
Pyrene	254000

Other Polynuclear Aromatic Compounds tested:

Carbazole	6940
Naphthalene	6230

The above results are reported in ug/Kg .

The above results are on an as received basis.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020340

Source: SR AN SOIL
Description: SLURRY REACTOR

Date Collected: 02/10/88
Date Received: 02/11/88

Date Extracted: 02/15/88
Date Analyzed: 02/24/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008144

Polynuclear Aromatic Hydrocarbons

Acenaphthene	:	458000
Acenaphthylene	:	7350
Anthracene	:	210000
Benzo(a)anthracene	:	163000
Benzo(a)pyrene	:	56700
Benzo(b)fluoranthene	:	80200
Benzo(g,h,i)perylene	:	59800
Benzo(k)fluoranthene	:	30000
Chrysene	:	160000
Dibenz(ah)anthracene	:	110000
Fluoranthene	:	563000
Fluorene	:	368000
Indeno(123-cd)pyrene	:	42600
Phenanthrene	:	1060000
Pyrene	:	528000

Other Polynuclear Aromatic Compounds tested:

Carbazole	:	11100
Naphthalene	:	8170

The above results are reported in ug/Kg .

The above results are on an as received basis.

All PAH identifications are from retention data only.

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE OF CONTENTS — PRODUCED ON 03/02/88 AT 10:30 — PAGE

SAMPLE #	SOURCE	DESCRIPT	DATE-COL	DATE-REC	ORD #
88020337	SR AER WATER	SLURRY REACTOR	02/10/88	02/11/88	M8802058
88020338	SR AN WATER	SLURRY REACTOR	02/10/88	02/11/88	M8802058

008145

KEYSTONE ENVIRONMENTAL RESOURCES, INC.

TABLE 1: SUMMARY OF ANALYTICAL DATA PRODUCED ON 03/02/88 AT 10:31 PAGE

SAMPLE #	RSLT. LNE		SOURCE
pH			
88020337	pH, units..... :	7.4	SR AER WATER
88020338	pH, units..... :	7.3	SR AN WATER

008146

KEYSTONE ENVIRONMENTAL RESOURCES, INC

TABLE 2: SUMMARY OF PAH DATA

Sample: 88020337

Source: SR AER WATER
Description: SLURRY REACTOR

Date Collected: 02/10/88
Date Received: 02/11/88

Date Extracted: 02/12/88
Date Analyzed: 02/24/88

Clean up Method

silica gel clean-up	✓ yes	___ no
florisil clean-up	___ yes	___ no
alumina clean-up	___ yes	___ no
sulfur clean-up	___ yes	___ no

008147

Polynuclear Aromatic Hydrocarbons

Acenaphthene	273
Acenaphthylene	35.5
Anthracene	42.0
Benzo(a)anthracene	16.5
Benzo(a)pyrene	3.20
Benzo(b)fluoranthene	4.81
Benzo(g,h,i)perylene	2.93
Benzo(k)fluoranthene	1.81
Chrysene	14.3
Dibenz(ah)anthracene	4.63
Fluoranthene	85.9
Fluorene	153
Indeno(123-cd)pyrene	1.77
Phenanthrene	167
Pyrene	69.4

Other Polynuclear Aromatic Compounds tested:

Carbazole	<2.00
Naphthalene	12.3

The above results are reported in ug/L.

All PAH identifications are from retention data only.

Case 1: Tar Plant
Process Wastewater
Pilot-Scale Unit

Parameter	Influent	Effluent	Percent Removal
Phenolics			
Phenols (4-AAP)	550	0.13	99.98
General Analytes			
Total Organic Carbon	2150	120	94.42

NOTE: All values expressed in mg/l unless otherwise noted.

008148

Case 2: Tar Plant
Process Wastewater
Laboratory Bench - Scale Unit

Parameter	Influent	Effluent	Percent Removal
Phenolics			
Phenols (4-AAP)	550	0.12	99.98
General Analytes			
Total Organic Carbon	2150	95	95.58

NOTE: All values expressed in mg/l unless otherwise noted.

008149

Case 3: Tar Plant
Process Wastewater
Pilot - Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia-N	38.5	< 1	> 98.87
Thiocyanate	370	< 1	> 99.73
Cyanide - Total	1.54	1.42	7.79
Metals			
Arsenic	0.404	0.135	66.58
Copper	3.5	1.2	65.71
Lead	0.06	0.05	16.67
Nickel	0.03	0.52	(+)
Selenium	0.056	0.315	(+)
Zinc	0.70	1.6	(+)
Mercury	0.0022	< 0.002	> 9.02
Purgeable Aromatics			
Benzene, ug/l	5	3	40
Phenolics			
Phenols (4-AAP)	1041	< 0.005	99+
Phenol	250	0.001	99+
Polynuclear Aromatic Hydrocarbons, ug/l			
Fluorene	14	0.25	98.2
Phenanthrene	32	0.80	97.5
Anthracene	10	0.20	98.0
Pyrene	5.1	0.30	94.1
Benz(a)anthracene	0.95	0.4	57.9
Chrysene	0.55	0.3	45.5
Benz(b)fluoranthene	0.2	0.25	(+)
Fluoranthene	112	10	91.07
Naphthalene	33	0.20	99.4
General Analytes			
Total Organic Carbon	1409	116	91.77
Oil and Grease	24	6	75.0

NOTE: All values expressed in mg/l unless otherwise noted.
< - Indicates detectable limit
(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

Case 4: Industrial Speciality Chemical Plant
Process Wastewater
Pilot-Scale Unit

Parameter	Influent	Effluent	Percent Removal
Phenolics			
Phenols (4-AAP)	348	0.78	99.78
Phenol/o-Cresol	2.77	< 0.49	> 82.31
General Analytes			
Total Organic Carbon	780	325	58.33
Oil and Grease	148	13.75	90.71

NOTE: All values expressed in mg/l unless otherwise noted.

< - Indicates detectable limits

Case 5: Coke Plant
Process Wastewater
Pilot-Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia-N	1131	4.05	99.64
Nitrate	1.49	25.28	(+)
Cyanide - Total	207.3	0.86	99.59
Thiocyanate	429.5	1.0	99.77
Metals			
Arsenic	0.068	BDL (0.35)	>26.47
Mercury	0.00096	0.00064	33.33
Zinc	0.23	0.12	47.83
Purgeable Aromatics			
Benzene	76.5	BDL (10)	99.
Toluene	14	BDL (10)	99.
Phenolics			
Phenols (4-AAP)	334	0.09	99.97
Phenol - Total	580	0.16	99.97
Polynuclear Aromatic Hydrocarbons (ug/l)			
Acenaphthylene	161	0.26	99.84
Acenaphthene	55	0.16	99.71
Fluorene	192	0.24	99.88
Phenanthrene	530	0.85	99.84
Anthracene	150	0.12	99.92
Fluoranthene	430	1.77	99.59
Pyrene	910	1.13	99.88
Benz(a)Anthracene	219	0.80	99.63
Chrysene	175	0.63	99.64
Benzo(b)Fluoranthene	192	1.42	99.26
Benzo(k)Fluoranthene	114	0.76	99.33
Benzo(a)Pyrene	245	1.73	99.29
Dibenz(a,b)Anthracene	38	0.25	99.34
Benzo(g,h,i)Perylene	173	1.25	99.28
Indeno (1,2,3-c,d)Pyrene	134	1.50	99.18
Naphthalene	256.67	1.23	99.52
General Analytes			
Oil and Grease	73.46	5.34	92.73
Total Organic Carbon	905	61.34	93.22
Total Dissolved Solids	7341	4465	39.18

NOTE: All values expressed in mg/l unless otherwise noted.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

BDL - Below Detection Limits.

Case 6: Coke Plant
Process Wastewater
Pilot-Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia-N	33.53	1.51	95.50
Nitrate	1.8	68.26	(+)
Thiocyanates	569.9	1.39	99.76
Cyanide - Total	241.5	2.96	98.77
Phenolics			
Phenols (4-AAP)	334	0.08	99.98
General Analytes			
Total Organic Carbon	826.9	67.18	91.88
Oil and Grease	17.34	5.8	66.55
Total Dissolved Solids	569.9	1.39	99.76

NOTE: All values expressed in mg/l unless otherwise noted.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

008153

008153

Case 7: Wood Treatment Plant
Process Wastewater
Laboratory Bench-Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia-N	16	19	(+)
Nitrate	11	6.5	41
Purgeable Aromatics, (ug/l)			
Benzene	31	BDL	-
Toluene	30	BDL	-
Phenolics			
Phenols (4-AAP)	89.60	1.57	98.24
Phenol	73	BDL	-
Polynuclear Aromatic Hydrocarbons, (ug/l)			
Acenaphthylene	26	0.60	97.69
Acenaphthene	494	1.8	99.64
Fluorene	533	0.9	99.83
Phenanthrene	1867	1.8	99.90
Anthracene	76	0.6	99.21
Fluoranthene	1095	59.0	94.61
Pyrene	766	18.7	97.56
Benzo(a)Anthracene	234	23.1	90.13
Chrysene	145	14	90.34
Benzo(b)Fluoranthene	85	13.4	81.88
Benzo(k)Fluoranthene	53	10.1	80.94
Benzo(a)Pyrene	34	13.6	81.43
Dibenzo(a,h)Anthracene	8	1.2	85.00
Benzo(g,h,i)Perylene	41	6.1	85.12
Indeno(1,2,3-c,d)Pyrene	36	5.5	84.72
Naphthalene	298	0.40	99.87
Metals			
Nickel -Total	0.15	BDL	-
Zinc - Total	0.30	.11	63.3
General Analytes			
Oil and Grease	96.6	38.6	60.04
Total Organic Carbon	769	171	77.74
Total Dissolved Solids	1121	446	60.22

NOTE: All values expressed in mg/e unless otherwise noted.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

BDL - Below Detection Limit.

008154

Case 8: Wood Treatment Plant
Process Wastewater
Laboratory Bench Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	21.4	18	17.94
Nitrate	0.95	0.57	40.00
Cyanide - Total	0.06	0.04	33.33
Metals			
Arsenic	0.03	0.05	(+)
Iron	27.00	17.58	34.89
Purgeable Aromatics			
Benzene	11	BDL	-
Toluene	11	BDL	-
Phenolics			
Phenols - (4-AAP)	91.19	0.17	99.81
Phenol	45	BDL	-
Polynuclear Aromatic Hydrocarbons, (ug/l)			
Acenaphthylene	52	0.7	98.65
Acenaphthene	878	1.7	99.81
Fluorene	705	1.2	99.83
Phenanthrene	1652	5.5	99.67
Anthracene	166	0.9	99.46
Pyrene	522	25.6	95.10
Benzo(a)anthracene	183	9.1	95.16
Chrysene	156	8.0	94.87
Benzo(b)Fluoranthene	73	17.1	76.58
Benzo(k)Fluoranthene	50	10.4	79.20
Benzo(a)pyrene	74	15.8	79.65
Dibenzo(a,h)anthracene	7	1.4	80.00
Benzo(g,h,i)perylene	35	8.2	76.57
Indeno (1,2,3-c,d)pyrene	32	3.5	89.06
Naphthalene	1351	1.8	99.87
Fluoranthene	862	27	96.87
General Analytes			
Oil and Grease	79.71	12.04	84.89
Total Organic Carbon	1028	151	85.30
Total Dissolved Solids	1807	789.5	56.30

NOTE: All values expressed in mg/l unless otherwise noted.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

BDL - Below Detection Limit.

Case 9: Wood Treatment Plant
Process Wastewater
Laboratory Bench Scale Unit

Parameter	Influent	Effluent	Percent Removal
Phenolics			
Phenols - (4-AAP)	135.25	0.09	99.93
General Analytes			
Oil and Grease	38.85	21.51	44.63
Total Organic Carbon	386.87	112.54	70.91
Total Dissolved Solids	608.55	360.15	40.82

NOTE: All values expressed as mg/l.

008156

Case 10: Wood Treatment Plant
Process Wastewater
Laboratory Bench Scale Unit

Parameter	Influent	Effluent	Percent Removal
Phenolics			
Phenols - (4-AAP)	135.25	0.03	99.98
General Analytes			
Oil and Grease	38.85	8.13	79.07
Total Organic Carbon	386.87	57.09	85.24
Total Dissolved Solids	608.55	510.55	16.10

NOTE: All values expressed as mg/l.

008157

Case 11: Industrial Products Plant (Tar)
Process Wastewater
Full Scale Unit

Parameter	Influent	Effluent	Percent Removal
Phenolics			
Phenols - (4-AAP)	110	0.23	99.79
Phenol	54	.003	99.9
Polynuclear Aromatic Hydrocarbons, (ug/l)			
Acenaphthene	219	BDL	-
Fluoranthene	209	9	95.7
Benzo(a)anthracene	< 93	< 42	≥ 54.84
Benzo(a)pyrene	BDL	30	(+)
Benzo(k)fluoranthene	BDL	< 21	(+)
Chrysene	< 93	< 42	≥ 54.84
Acenaphthylene	181	3	98.3
Anthracene	< 850	< 8	≥ 99.06
Fluorene	221	BDL	-
Phenanthrene	850	8	99.06
Pyrene	156	10	93.6
Naphthalene	10300	1	99.9
Purgeable Aromatics, (ug/l)			
Benzene	3540	3	99.9
Toluene	6920	8	99.8
Xylene	9900	57	99.4
General Analytes			
Total Organic Carbon	1164	63	94.59

NOTE: All values expressed in mg/l unless otherwise noted.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

BDL - Below Detection Limits.

- Indicates detectable limit.

008158

Case 12: Industrial Products Plant (Tar)
Process Wastewater
Pilot Plant Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	233	117.8	49.44
Thiocyanate	358	1.18	99.67
Cyanide - Total	0.28	0.18	35.71
Phenolics			
Phenols - (4-AAP)	37.3	0.32	99.14
General Analytes			
Oil and Grease	39.30	10.29	73.82
Total Organic Carbon	839	53.6	93.61

NOTE: All values expressed in mg/l.

008159

Case 13: Industrial Products Plant (Tar)
Process Wastewater
Pilot Plant Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	258	5.49	97.83
Thiocyanate	88.7	0.96	98.92
Cyanide - Total	0.81	0.54	33.33
Phenolics			
Phenols - (4-AAP)	34.3	0.31	99.09
General Analytes			
Oil and Grease	91	5.92	93.49
Total Organic Carbon	918	45.9	95.00

NOTE: All values expressed in mg/l.

008160

Case 14: Industrial Products Plant (Tar)
Process Wastewater
Pilot Plant Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	199	0.39	99.80
Thiocyanate	116	0.91	99.22
Cyanide - Total	1.1	1.13	(+)
Phenolics			
Phenols (4-AAP)	33.1	0.33	99.00
General Analytes			
Oil and Grease	571	6.9	98.79
Total Organic Carbon	978	57	94.17

NOTE: All values expressed in mg/l

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment unit.

008161

Case 15: Industrial Products Plant (Tar)
Process Wastewater
Pilot Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	155	2.19	98.58
Thiocyanate	77.2	1	98.7?
Cyanide - Total	0.33	0.81	(+)
Phenolics			
Phenols - (4-AAP)	16.7	0.56	98.47
General Analytes			
Oil and Grease	53.2	5.5	83.72
Total Organic Carbon	836	59.1	92.93

NOTE: All values expressed in mg/l.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variation in influent and effluent concentrations due to time lag across the treatment section.

Case 16: Industrial Products Plant (Tar)
Process Wastewater
Pilot Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	151	1.12	99.26
Thiocyanate	75.1	0.78	98.96
Cyanide - Total	0.72	1.03	(+)
Phenolics			
Phenols - (4-AAP)	35.1	0.44	98.75
General Analytes			
Oil and Grease	105	6.2	94.10
Total Organic Carbon	1170	74.4	93.64

NOTE: All values expressed in mg/l.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment unit.

008163

Case 17: Industrial Products Plant (Tar)
Process Wastewater
Pilot Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	318	15.1	95.25
Thiocyanate	108	0.88	99.19
Cyanide - Total	1.12	1.45	(+)
Phenolics			
Phenols - (4-AAP)	26.8	0.26	99.03
General Analytes			
Oil and Grease	61.5	4.57	92.57
Total Organic Carbon	1150	40.8	96.45

NOTE: All values expressed in mg/l.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

008164

Case 18: Industrial Products Plant (Tar)
Process Wastewater
Pilot Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	207	82.7	60.05
Thiocyanate	52.6	0.516	99.02
Cyanide - Total	0.51	0.61	(+)
Phenolics			
Phenol	24.6	0.28	98.86
General Analytes			
Oil and Grease	60	< 5	> 91.67
Total Organic Carbon	1370	59.40	95.66

NOTE: All values expressed in mg/l.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

< - Indicates detectable limit.

Case 19: Industrial Products Plant (Tar)
Process Wastewater
Pilot Scale Unit

Parameter	Influent	Effluent	Percent Removal
General Inorganics			
Ammonia - N	285	267	6.32
Thiocyanate	99	2	97.98
Cyanide	0.81	1.83	(+)
Phenolics			
Phenols - (4-AAP)	20.9	0.35	98.33
Phenol	12.5	0.003	99.9
Purgeable Aromatics, (ug/l)			
Benzene	5350	< 1	> 99.9
Toluene	5570	2	99.6
Xylene	11400	12	99.8
General Analytes			
Oil and Grease	21.3	< 5	> 76.53
Total Organic Carbon	1460	616	57.81
Polynuclear Aromatic Hydrocarbons, (ug/l)			
Acenaphethene	337	BDL	-
Fluoranthene	341	BDL	-
Benzo(a)anthracene	≤ 235	BDL	-
Chrysene	235	BDl	-
Acenaphthylene	254	< 1	> 99.6
Anthracene	≤ 1215	< 2	≥ 99.8
Fluorene	344	BDL	-
Pyrene	218	BDL	-

NOTE: All values expressed in mg/l unless otherwise noted.

(+) - Denotes an increase in concentration from influent to effluent. This may be due to analytical anomalies at low concentration levels or variations in influent and effluent concentrations due to time lag across the treatment section.

BDL - Below Detection Limit.

< - Indicates Detectable Limit.

008166